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A SERIES OF TEXTBOOKS FOR PERSONS ENGAGED IN THE ENGINEERING PROFESSIONS AND TRADES OR FOR THOSE WHO DESIRE INFORMATION CONCERNING THEM. FULLY ILLUSTRATED AND CONTAINING NUMEROUS PRACTICAL EXAMPLES AND THEIR SOLUTIONS

MACHINE MOLDING
FOUNDRY APPLIANCES
MALLEABLE CASTING
BRASS FOUNDING
BLACKSMITHING AND FORGING

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PREFACE

The International Library of Technology is the outgrowth of a large and increasing demand that has arisen for the Reference Libraries of the International Correspondence Schools on the part of those who are not students of the Schools. As the volumes composing this Library are all printed from the same plates used in printing the Reference Libraries above mentioned, a few words are necessary regarding the scope and purpose of the instruction imparted to the students of—and the class of students taught by—these Schools, in order to afford a clear understanding of their salient and unique features.

The only requirement for admission to any of the courses offered by the International Correspondence Schools is that the applicant shall be able to read the English language and to write it sufficiently well to make his written answers to the questions asked him intelligible. Each course is complete in itself, and no textbooks are required other than those prepared by the Schools for the particular course selected. The students themselves are from every class, trade, and profession and from every country; they are, almost without exception, busily engaged in some vocation, and can spare but little time for study, and that usually outside of their regular working hours. The information desired is such as can be immediately applied in practice, so that the student may be enabled to exchange his present vocation for a more congenial one or to rise to a higher level in the one he now pursues. Furthermore, he

wishes to obtain a good working knowledge of the subjects treated in the shortest time and in the most direct manner possible.

In meeting these requirements, we have produced a set of books that in many respects, and particularly in the general plan followed, are absolutely unique. In the majority of subjects treated the knowledge of mathematics required is limited to the simplest principles of arithmetic and mensuration, and in no case is any greater knowledge of mathematics needed than the simplest elementary principles of algebra, geometry, and trigonometry, with a thorough, practical acquaintance with the use of the logarithmic table. To effect this result, derivations of rules and formulas are omitted, but thorough and complete instructions are given regarding how, when, and under what circumstances any particular rule, formula, or process should be applied; and whenever possible one or more examples, such as would be likely to arise in actual practice—together with their solutions—are given to illustrate and explain its application.

In preparing these textbooks, it has been our constant endeavor to view the matter from the student's standpoint, and to try and anticipate everything that would cause him trouble. The utmost pains have been taken to avoid and correct any and all ambiguous expressions—both those due to faulty rhetoric and those due to insufficiency of statement or explanation. As the best way to make a statement, explanation, or description clear is to give a picture or a diagram in connection with it, illustrations have been used almost without limit. The illustrations have in all cases been adapted to the requirements of the text, and projections and sections or outline, partially shaded, or full-shaded perspectives have been used, according to which will best produce the desired results. Half-tones have been used rather sparingly, except in those cases where the general effect is desired rather than the actual details.

It is obvious that books prepared along the lines mentioned must not only be clear and concise beyond anything

heretofore attempted, but they must also possess unequaled value for reference purposes. They not only give the maximum of information in a minimum space, but this information is so ingeniously arranged and correlated, and the indexes are so full and complete, that it can at once be made available to the reader. The numerous examples and explanatory remarks, together with the absence of long demonstrations and abstruse mathematical calculations, are of great assistance in helping one to select the proper formula, method, or process and in teaching him how and when it should be used.

Four of the volumes of this library are devoted to subjects pertaining to shop and foundry practice. The present volume, the fourth of the series, treats on the following subjects: machine molding, foundry appliances, malleable casting, brass founding, and blacksmithing and forging. The first four of the subjects named form a continuation of the treatment of molding and foundry practice. Special attention is called to the paper on Malleable Casting; this is believed to be the first attempt in print to give reliable information concerning this extremely important subject, and this feature alone will render the volume of great value to any one interested in malleable casting. The papers on Blacksmithing and Forging include heating furnaces and handling devices, and a treatment of soldering, brazing, and sweating.

The method of numbering the pages, cuts, articles, etc. is such that each subject or part, when the subject is divided into two or more parts, is complete in itself; hence, in order to make the index intelligible, it was necessary to give each subject or part a number. This number is placed at the top of each page, on the headline, opposite the page number; and to distinguish it from the page number it is preceded by the printer's section mark (§). Consequently, a reference such as § 37, page 26, will be readily found by looking along the inside edges of the headlines until § 37 is found, and then through § 37 until page 26 is found.

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MACHINE MOLDING.

SMALL MACHINES.

RAMMERS AND MOLDING MACHINES.

PNEUMATIC RAMMERS.

1. Rammers for Light Work.—A form of **pneumatic rammer** for light work is shown in Fig. 1 (*a*), which is operated by air under a pressure of from 40 to 90 pounds per square inch. It consists of a cylinder *a* supported at the middle on trunnions *b*, *b* that have their bearings in a frame *c*. This form is provided with two rammers *d* and *e*, one at each end *f* and *g* of the piston rods, which extend beyond the ends of the cylinder. One of the rammers is a peen *d* and the other *e* a butt rammer. Either of these may be used at will by swinging the cylinder on its trunnions so that the desired one stands downwards. The stroke of the piston is regulated by an ingeniously constructed automatic reversing valve. The air is supplied through a hose *h*. A wire rope *i*, which passes over a pulley and carries a counterweight, is attached to an eyebolt *j* in the top of the machine.

A pneumatic rammer strikes from 200 to 300 blows per minute and requires one man to operate it. It is equally economical and applicable for green-sand, loam, floor, or machine work. It strikes with uniform pressure, and hence

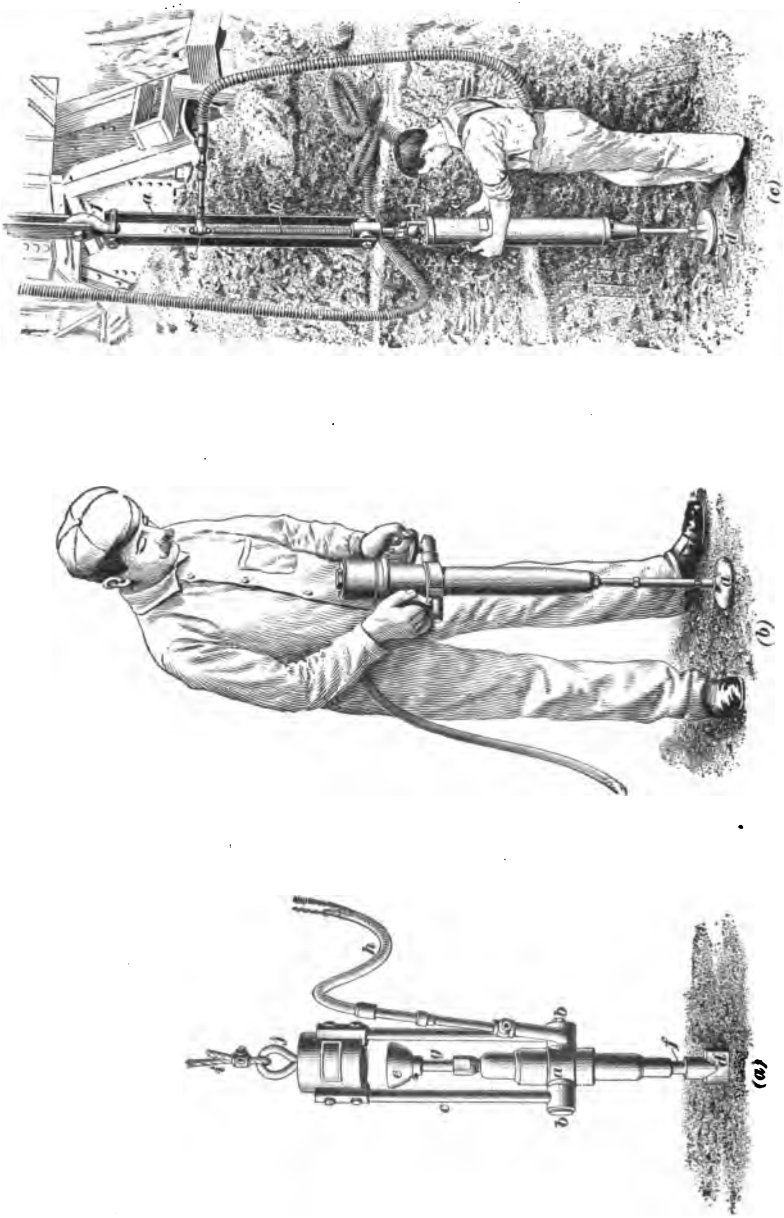


FIG. 1.

the ramming can be done more evenly and far better than by hand. In Fig. 1 (*b*) is shown a portable form of pneumatic rammer that is held by handles attached to the cylinder. This form has only one rammer *a*. The end of the piston rod is constructed in such a manner that either a peen or a butt rammer may be attached to it. The flow of air is controlled by a valve operated by a small trigger in the right-hand handle.

2. Rammers for Heavy Work.—In Fig. 1 (*c*) is shown another form that is especially serviceable for backing up large and deep molds, which ordinarily takes a large gang of men several days to ram them in the old way. This rammer is attached to the supporting frame *a* by means of a long screw *b*. By rotating the rammer by means of the handles *c*, *c*, while it is operating, it is lowered or raised as required to allow the tamping plate *d* to reach the sand in the molds. The screw is hollow and serves to conduct the air to the cylinder from the hose that is attached by means of a swivel coupling *e*. The hook *f* serves to attach the rammer to a hoist on the trolley of a jib crane or some similar support that will permit the rammer to be easily shifted over the surface of the mold. A mold occupying a pit 30 feet long, 14 feet wide, and 8 feet deep requires, according to regular practice, about 25 men 3 days to ram up the sand back of the mold ready for casting. With two ramming machines of the form shown in Fig. 1 (*c*), 12 men can fill and ram it in 1 day.

MOLDING MACHINES.

3. The principal mechanical operations in molding consist of filling the flasks with sand, ramming, and withdrawing the pattern. The filling is usually done by hand or with the aid of overhead conveyers. Molding machines perform mechanically a limited number of the operations that are necessary to produce a complete mold. In some machines

preference is given to the ramming, in others to the drawing of the patterns, while others are provided with facilities for filling the molds with sand, and a few of the latest designs include devices for rapping the patterns. Some machines perform several of the molding functions, but none combine all of them at the same time. A large portion of the work necessary to complete a mold is left in all cases to be done by hand. Many attempts have, however, been made to do away entirely with all-hand work, and to produce mechanically complete molds with the aid of machinery, but without success. The ideal molding machine will be one that makes a complete mold with the least complicated mechanism. In order to be successful, it should be simple in construction and operation, and by its use the cost of castings should be lessened. It is not only necessary to cheapen some one or more of the molding operations, but the cost of others must not be increased.

The economical use of molding machines requires good judgment on the part of the superintendent and foreman of the foundry and ordinary intelligence and good will on the part of the operator. It is not economical to mold a few small articles in large flasks and on large or heavy machines, flat work on machines with deep draft, to use plain patterns with easy draft on stripping-plate machines, or mold round shapes in square flasks.

Manufacturers of molding machines design and construct them to suit nearly all conditions, and if they are to be used for producing a continuous run of the same kind of casting, machines adapted to that special need will be found the most economical.

4. Mold Presser.—A **mold presser,** sometimes called a **squeezer,** is the simplest form of molding machine. Such machines are suitable for molding flat articles, as builders' hardware, stove lids, washers, wrenches, etc., which are molded mostly in snap flasks. The object of the machine is to obviate the hand-ramming operation and to increase the daily output of the molder.

A simple form of machine for pressing the molds is shown in Fig. 2, in which the mechanism is all above the flask and the sand, and hence the working parts of the machine receive no injury from this source. The sand is pressed into the flask *a* by a presser head *b*, which is lowered on top of the follow board *c* by means of the hand lever *d* and a geared eccentric and toggle-joint in the case *e*. The machine is fastened to a post *f* by means of a bolt that passes through a slot *g*, thus making provision for a vertical adjustment over the table *h*. A counterweight *i* automatically lifts the presser head when the hand is removed from the lever. The portable form of this machine is placed on a truck.

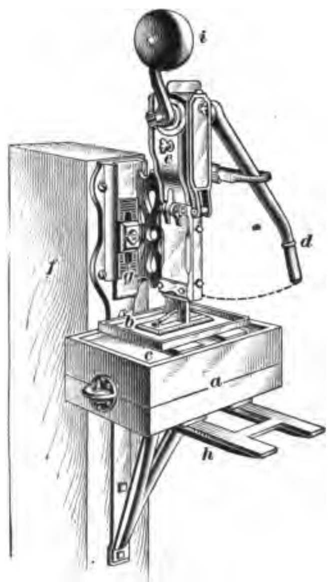


FIG. 2.

5. Another style of machine for pressing the molds is shown in Fig. 3, and consists of a frame with a table *a* to support the flask, and a lever *b* by means of which the plate *c* is lowered on the surface of the molding sand, pressing it into the flask. The illustration shows the sand being pressed into the drag *d*, which is placed over the patterns on a match board *e* on the table *a* of the machine. After pressing the sand in the drag, the presser head *c* is thrown back, the mold turned over, the match board removed, parting sand applied, and the cope *g* placed over the drag *d*. The sand is then pressed in the cope in the same manner as described for the drag. The presser head is then thrown back out of the way, the sprue is cut, and the pattern wrapped by striking against a pin that is held in the left hand so as to stand in the sprue with the lower end in contact with the pattern;

after which the flask is separated, the pattern withdrawn, and the mold placed on the floor to be poured. The power is applied to the lever *b* by the operator simply straightening his arm and putting his weight on it, pressing every mold alike, and with little care or judgment on his part. The ratio of the leverage being 30 to 1, a 135-pound man will exert a pressure of 2 tons on the mold without much muscular effort.

FIG. 3.

The shelves *h* are used for holding brushes, sprue cutters, and a box *i* of parting sand, and the upper shelf especially for holding the match or presser boards. The table *j* is necessary to hold parts of a flask, or molds, or the match boards, etc.

This type of molding machine is suitable for flasks not over 24 inches in length, 18 inches in width, and 10 inches in depth. It is also portable, being easily moved about the foundry floor on the rollers *k*, *k*.

6. Another form of mold presser is shown in Fig. 4. In the machines illustrated in Figs. 2 and 3 the presser head is lowered on the sand, while in the machine illustrated in Fig. 4 the sand is compressed in the flask between the presser head *a* and the table *b* by the vertical movement of the table; this operation is performed by means of the lever *c* turning the shaft that carries the eccentrics *d*, *d* and thus lifts the rods *e*, *e* that support the table *b*. The height of the

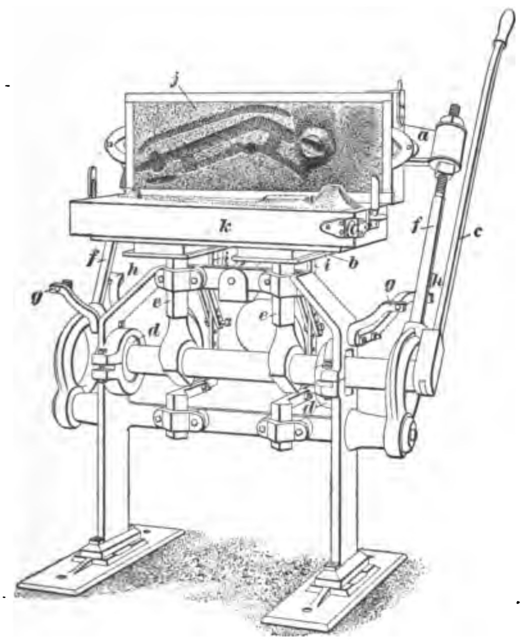


FIG. 4.

presser head is adjusted by means of the thread and nuts on the upper ends of the side rods *f*, *f*. The stops *g*, *g* determine the position of the side rods *f*, *f* to bring the presser head over the mold, and the stops *h*, *h* support the rods when the presser head *a* is thrown back so that the mold can be opened. Two brackets *i*, *i* support a shelf at the rear of the table *b* for holding the cope *j* when the mold is opened to remove the pattern, as shown in the illustration; the presser head *a* moves back far enough to give ample room

for the cope to rest edgewise on the table back of the drag *k*. The pattern in the mold shown is for a gas burner for a stove.

7. Capacity of a Molding Machine.—The capacity of a machine depends on the size of the flask used, the amount of sand to be handled, the condition and the shape of the patterns, the exertion required to operate the machine, and the distance to which the finished molds must be carried.

With stationary molding machines and no mold conveyer, considerable time and labor is consumed in placing the finished flasks on the molding floor. Assuming that each molder completes 200 14″ × 14″ flasks and places them in four parallel rows with a space of 3 inches between them, with 5 feet between the machine and the nearest flask, the last flasks will be located about 76 feet from the machine. This will necessitate the carrying of each flask an average of about 40 feet, or the total travel is equal to carrying a single flask over a distance of 8,000 feet.

8. Portable Molding Machines.—Under the conditions mentioned, the portable type of machine is preferable, as it is easily moved from end to end of the molding floor. Some portable machines have grooved wheels, which allow them to be run on tracks laid on the foundry floor. The molding sand for portable-machine work is piled up in long heaps on one side of the tracks, or between the legs of the machine, and the bottom boards and the empty flasks are arranged on the other side. The molding operation commences at one end of the floor; the finished molds are placed where the sand heap was located at the beginning of the molding operation, that is, where it was cut up, mixed, and tempered for the following heat. The portable machine becomes especially serviceable when the shape of the pattern is such that the whole mold cannot be made on one machine. In such cases two machines are used; the drag is finished with one and the cope with the other, the work being done by different operators. The first operator places the drag on the bottom board upon the molding floor, where cores may be inserted if necessary, and the second operator follows with the cope

and closes the mold. This method generally requires about double the amount of labor for handling the molds.

9. Machines for Drawing Patterns.—Some founders consider the withdrawal of the patterns from the sand one of the expensive molding operations, as it requires considerable time, and often, by the ordinary methods, both the pattern and the mold are injured. Machines have therefore been made for the purpose of handling the patterns more economically than can be done by hand.

A machine for withdrawing the patterns from the molds mechanically by means of a vacuum cup is shown in Fig. 5. A frame hinged to a post at *a*, *a* carries a metal tube with a rubber cup-shaped suction disk *c* at its lower end. The tube is supported by means of a cord *d* passing over a pulley *e* in the upper arm *b* and attached to a counterweight *f*. A rubber tube *g* connects the upper end of the vertical metal tube, attached to the disk *c*, to a vacuum pump. The method of operation consists in bringing the disk *c* into contact with the pattern in the flask *h* by means of the hand lever *i*. The patterns are usually attached to a mold board *k* unless they have sufficiently large flat surfaces to which the suction disk may be attached. A vacuum is established in the cup *c* by operating either of the foot-levers *j*. The lever may operate a foot-power vacuum pump, or the

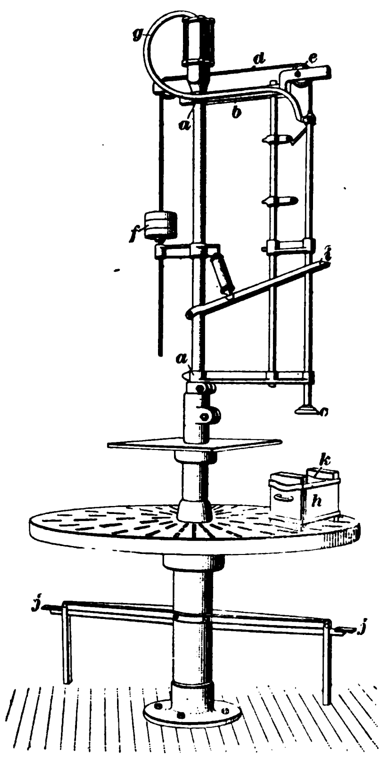


FIG. 5.

machine may be arranged so that connection is made by means of a valve to a power-operated pump. When the hand lever i is raised the pattern is lifted vertically from the mold by means of the vacuum between the disk and the pattern. The machine will draw deep patterns as quickly as shallow ones, and the drawing operation is *upwards* from the sand; this obviates some of the disadvantages experienced when patterns are withdrawn *downwards* from the sand, such as the use of nails and gaggers and the necessity of much swabbing and patching of the mold.

10. Stripping-Plate Molding Machine.—In this style of machines the patterns are withdrawn mechanically by stripping them through a plate having openings that

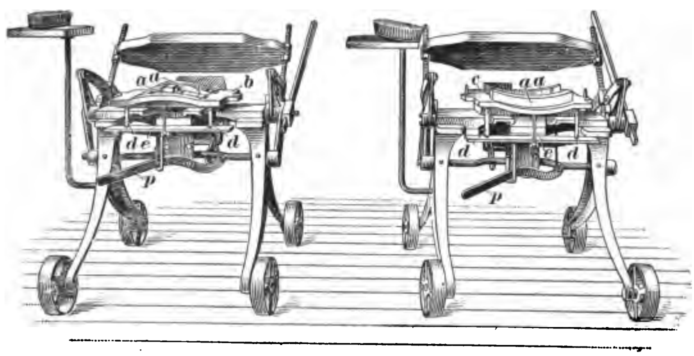


FIG. 6.

exactly conform to the outline of the patterns. Fig. 6 illustrates a pair of molding machines equipped with stripping-plate patterns a for brake shoes. Fig. 7 (a) and (b) show the arrangement of the patterns a in the stripping plate b, Fig. 7 (a) being the stripping plate for the cope, and c, Fig. 7 (b) the stripping plate for the drag. Details of the pattern are shown at a', a', Fig. 7. The patterns are drawn from the sand by raising the stripping plates b and c with the mold from the patterns that remain fixed on the machine tables. The pattern plates to which the patterns are

fastened on the machine tables, and also the flasks, have irregular parting lines to fit the curved stripping plates. The pattern plates in these machines rest firmly on and are

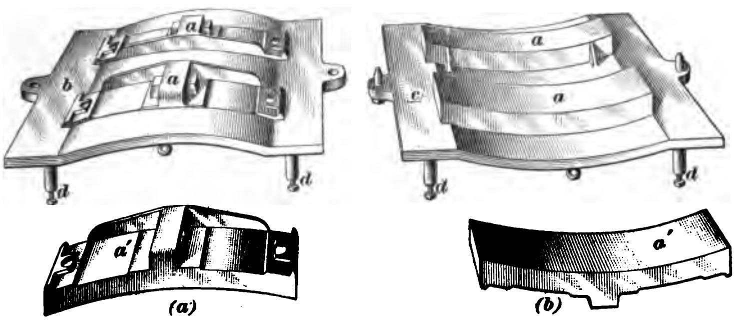


FIG. 7.

attached to the stationary part of the frame of the machine, and the stripping plates *b* and *c*, shown in Fig. 6, rest on the pattern plates, and are raised by means of four legs *d* that rest on the lifting table *e*; the table *e* is raised by means of a lever *p*. Owing to the fact that some parts of the patterns extend a considerable distance above the parting line, it is not possible to obtain a solid mold by pressing the sand

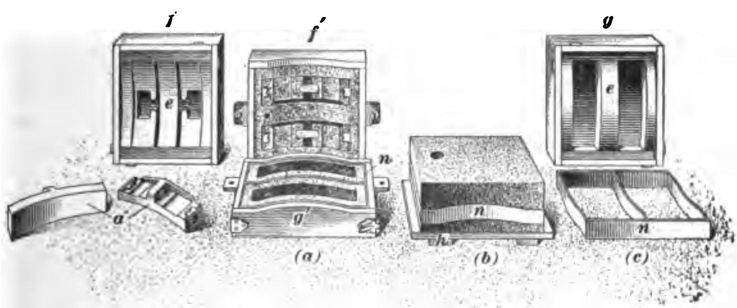


FIG. 8.

with a flat surface. On this account especially shaped presser heads *e*, Fig. 8, are used to press the sand between the patterns in the cope *f* and drag *g*, as shown in (*a*) and (*c*).

These heads press the sand between the patterns and insure even ramming of the entire mold. After the parts of the flask are rammed in this manner, the presser heads *e* are removed, the flask struck off, and the lifting levers *p*, shown in Fig. 6, raised, which lift the stripping plates *b* and *c* and the molds off the patterns *a*. In Fig. 8 (*a*) is shown a finished cope *f′* and drag *g′* before closing. Fig. 8 (*b*) shows a complete mold on a bottom board *h*, and Fig. 8 (*c*) shows a band *n* that is inserted in the cope portion of the flask before ramming. After the snap flask has been removed, the band *n* remains in the mold, as shown in Fig. 8 (*b*), and holds the mold together against the pressure of the fluid iron.

11. Molding Machine Without Stripping Plate. A machine with a pattern plate, but without a stripping

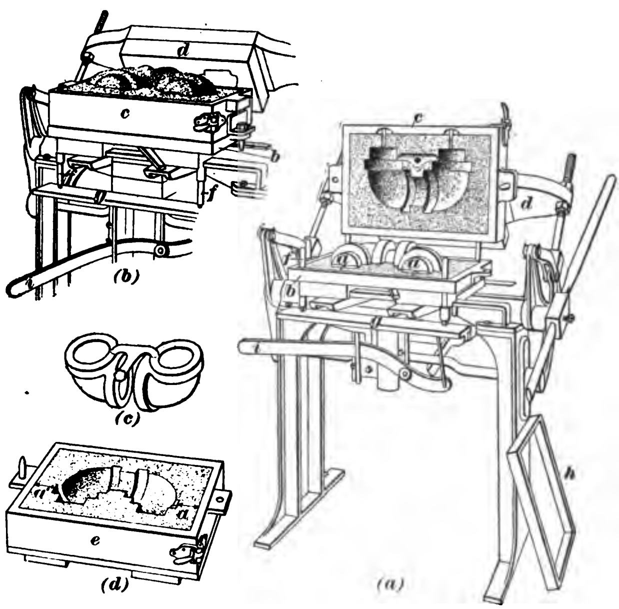


FIG. 9.

plate, is shown in Fig. 9 (*a*) and (*b*). The half patterns ***a, a*** for the two cast elbows, which are shown connected by the gate as they come from the mold in Fig. 9 (*c*), are shown on

the pattern plate *b*, which is fastened to the table of the machine. In this case, the impressions made in the sand of the cope and the drag are alike. In order that the two parts of the mold may fit accurately together, it is necessary that the patterns be so arranged on the pattern board that the distances *a*, *a'* from the edges of the pattern to the ends of the flask, shown in Fig. 9 (*d*), be the same. When the two parts of the pattern are very unlike, or when it is necessary to pour the mold with a certain side up, two machines are used, one having the patterns for the cope, and the other those for the drag. In Fig. 9 (*b*) is shown the cope *c* after having been pressed with the presser head *d*, the under side of which conforms to the shape of the patterns, and leaves the extra sand *e* on top of the cope. This gives approximately the same depth of sand at all points of the mold and so insures even ramming. The conforming presser head is used in the case of deep patterns. Before filling the flask with sand, a sand frame *h*, shown in Fig. 9 (*a*), is placed on top of the flask, which increases the depth of the flask enough to hold the additional sand necessary to fill the flask when the bottom board and presser head are forced in. The extra sand *e* is struck off before the flask is lifted from the machine. The flask is lifted from the patterns by means of four pins *f*, one at each corner of the pattern plate, whose lower ends rest on the lifting table *g*. The pins move vertically through sleeves in the pattern plate *b*, and lift the flask from the patterns when the lifting lever *i* is raised, as shown in Fig. 9 (*a*).

If the patterns require jarring when the flask is being lifted, the pattern plate is lifted with a projection at the right-hand corner, and this is rapped by a bar held in the right hand of the operator, while he lifts the lever *i* with his left hand.

12. Pneumatic-Power Molding Machine. — Several forms of mold-press machines are arranged to operate by means of compressed air, one of which is shown in Figs. 10 and 11. In this machine the table *a* is attached to

a cylinder *b* that slides over a stationary plunger *c*. The table *b* moves upwards when compressed air is admitted to the cylinder, and presses the sand in the flask *d* between the table and the presser head. In the illustrations, the presser head *e* is shown tilted back to enable the flask to be put in position or removed. An air pressure of about 75 pounds

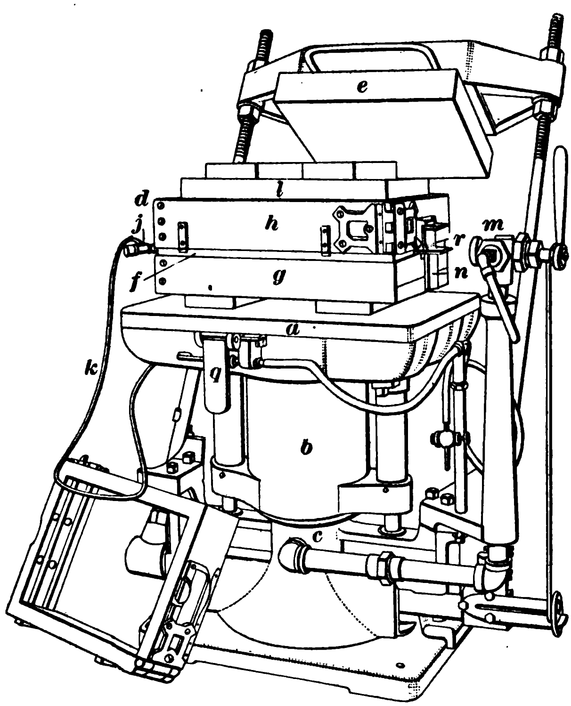


FIG. 10.

per square inch is used. The ordinary solid and gated patterns are made available for use on this machine by attaching them to a vibrator frame *f*. The vibrator frame is shown in detail in Fig. 12. This frame is placed between the match *g* and drag *h*, as shown in Fig. 10, while making the drag, and between the cope *i* and drag *h*, as shown in Fig. 11, while making the cope. The vibrator *j*, which is

attached to the corner of the frame, as shown in Figs. 10 and 12, consists of a small valveless plunger arranged to vibrate back and forth between two hardened anvils in a cylinder. When compressed air is supplied to the vibrator by means of the hose *k*, Figs. 10 and 11, its action sets up a sharp tremor in the frame and the patterns attached to it,

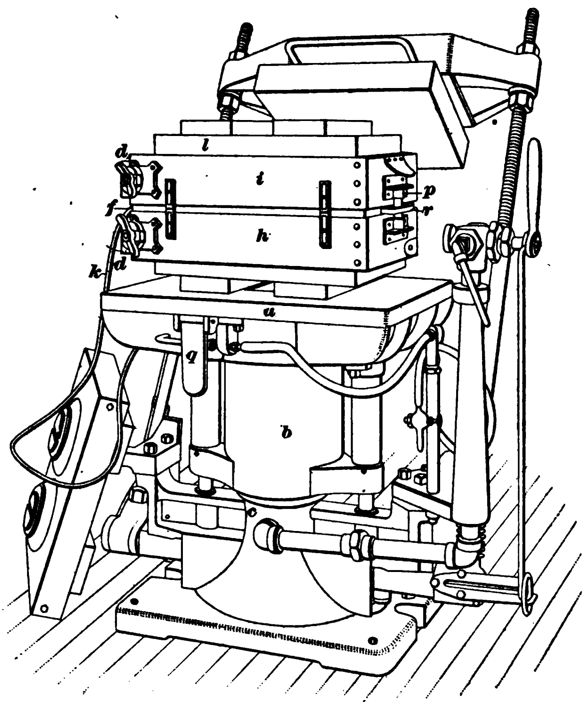


FIG. 11.

and the patterns are lifted from the sand without hand rapping. To operate the machine, the match *g* with the vibrator frame *f* and patterns are laid on the machine table *a*. The drag *h* is placed in position, filled with sand and pressed. To press the sand, the presser board *l* is placed on the drag, the presser head *e* is swung over the table, and the air admitted to the cylinder by means of the three-way cock *m*.

After ramming the mold, the air is exhausted from the cylinder and the table lowers by gravity; the presser head is pushed back and the match and drag rolled over on the table by hand in the usual way; the match is removed,

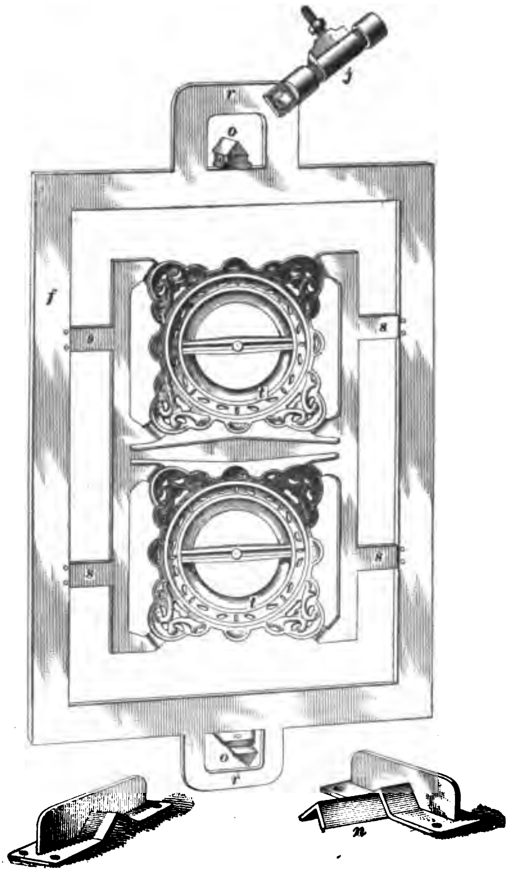


FIG. 12.

parting sand applied to the face of the mold in the drag, and the cope placed in position, filled with sand and pressed by the machine in the same manner as described for the drag. Snap flasks are generally used, though interchangeable solid

iron flasks can be adapted to the machine. In order that the different parts of the flask and the vibrator frame may come together accurately in forming the mold, special V-shaped pins *n* and *o*, shown in Fig. 12, are used. The drag pins *n* slide over the vibrator frame pins *o*, and enter the sockets *p* of the cope. After ramming the cope, the presser head is thrown back and the flask left in position for the cope to be removed. The sprue is cut either by hand in the usual way, or in some cases automatically by means of sprue cutters attached to the presser head. A lever *q* under the edge of the table *a* admits air to the vibrator. When the operator grasps the cope with his hands, he presses the lever *q* with his left knee and the cope is lifted while the vibrator is running; the vibrator is also operated while the frame is being lifted off, the lifting being done by means of its two handles *r*, *r*. The patterns are guided vertically from the sand by means of the V-shaped pins *o*, attached to the frame shown in Fig. 12, and can be easily and accurately replaced in the mold if necessary. The prints in the mold made by the bars *s*, *s*, etc., which are used to attach the patterns *t* to the frame, as shown in Fig. 12, must be filled with sand before the flask is closed and poured, unless they are used as core prints and closed by the cores.

13. Automatic Molding Machine.—In Fig. 13 is shown an automatic molding machine designed to perform mechanically the various operations in making molds by means of flasks and match boards. The machine is operated by means of a counterbalanced hand lever *a* that lifts the table *b*, with the flask *c* lying on it, against the presser head, thus pressing the sand into the flask. The machine has a turret top, composed of three parts, which revolves on a shaft *d* carried by the side rods *e*, *e*. The pattern plate *f* is attached to a system of levers so that it can be moved horizontally and held either in the flask centrally over the table, as shown in (*b*), (*d*), and (*e*), or to the rear of the flask. The flasks are either of wood or iron, and are made with solid corners. They are made tapering so as to be

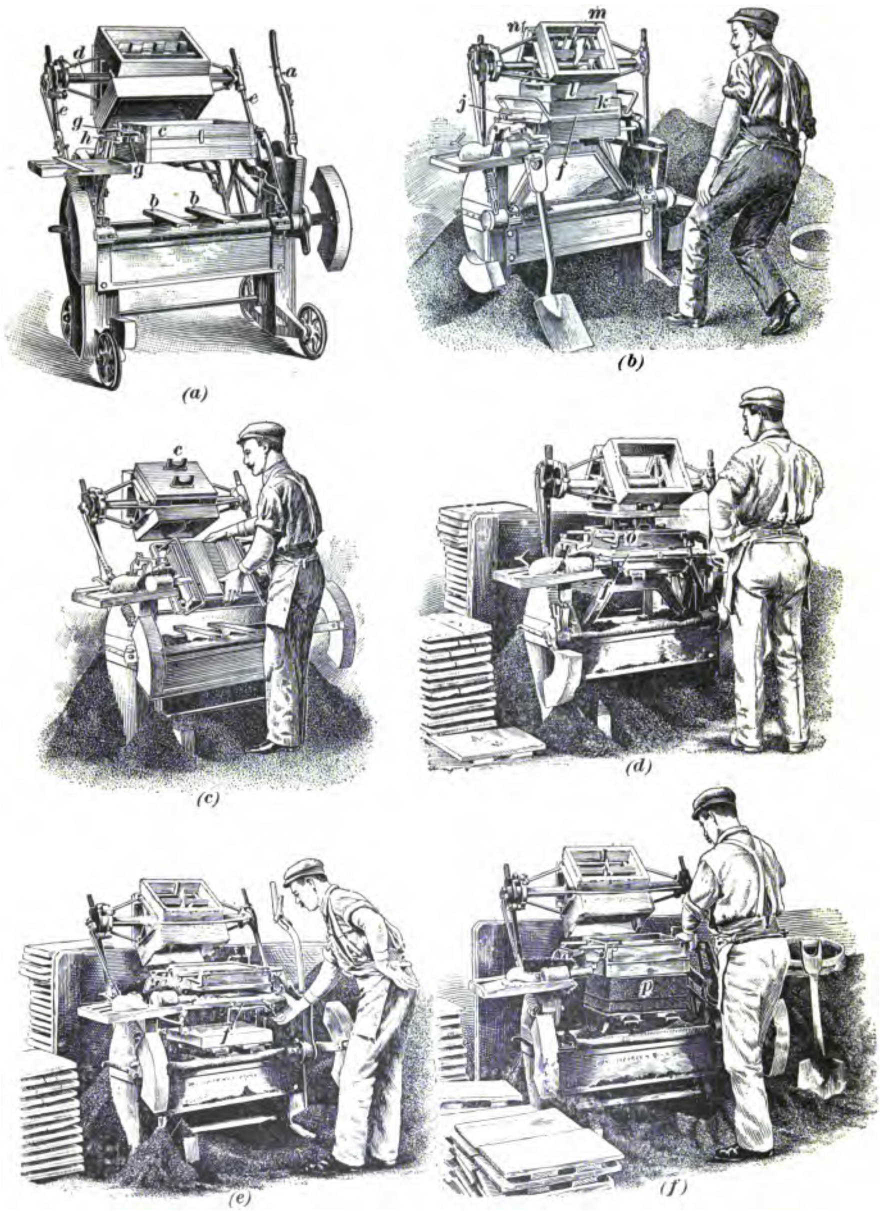


Fig. 18.

easily lifted from the molds, and have movable ribs for holding the sand in the mold. The ribs are withdrawn flush inside the flask, and at the same time the two parts of the flask are locked together, when the mold is completed and ready for the flask to be removed. The flask is held in place on the machine by means of pins *g* engaging a frame *h*. The pattern plate *f* is clamped to a frame *i*, as shown in Fig. 14,

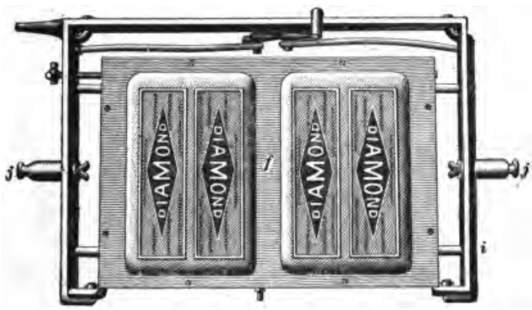


FIG. 14.

and is supported on the machine by means of the trunnions *j*, *j*, as shown in Fig. 13 (*b*) and Fig. 14. To operate the machine, the frame with pattern plate is placed between the two parts of the flask on the table, the drag *k* being on top, as shown in Fig. 13 (*b*). The drag is filled with sand, and the peening frame *l* on the turret top is pressed into it. The flask is lowered and the surplus sand struck off; a bottom board is placed on, and the flask revolved by hand, as shown in (*c*). The cope is then filled with sand and the cope peening head *m* pressed into it; the surplus sand is struck off, and the presser head *n* automatically applied, thus pressing both cope and drag in one operation; the presser head enters the top of the cope and the bottom board is forced into the drag. Sprue cutters may be attached to the presser board, or flat gates *o* can be placed on the pattern, just before the cope is filled with sand, and are withdrawn by the head automatically, as shown in (*d*). The flask is then separated as shown in (*e*) and the pattern plate *f* passed to the rear. In (*e*) the operator is just removing the pattern board from the cope to pass it to the rear of the mold. The two halves

of the flask are then brought together and the bottom board lowered with the complete mold *p* on the table, as shown in (*f*). The mold is then placed on the floor ready to be poured. A shelf attached to the left side of the machine holds a brush, wooden mallet, and other necessary tools, and a sack of parting sand or facing. The machine is made to run on a track.

14. Molding Machine Without Rammer. — Fig. 15 (*a*) and (*b*) shows a pair of stripping-plate machines

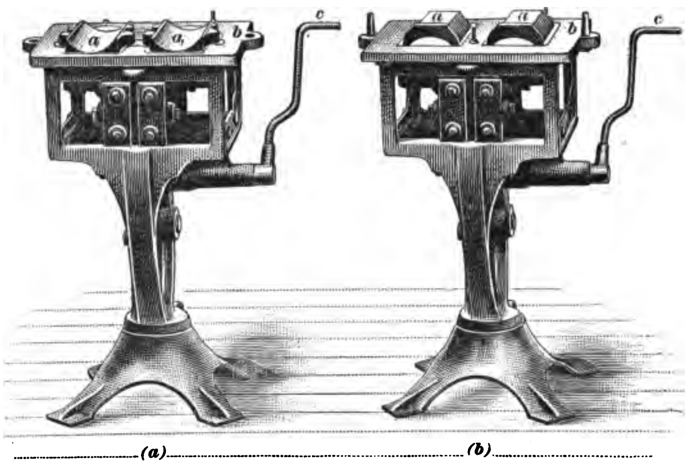


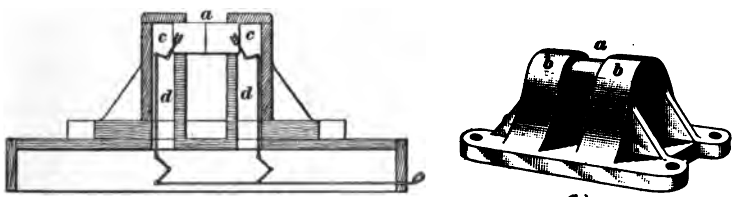
FIG. 15.

that do not ram the molds, this operation having to be performed by hand or by means of some mechanical device that is entirely separate from the machine. The machines are shown equipped with patterns *a* for railway-car journal bearings. The stripping plates *b*, *b* rest on the top of the frame of the machines. The patterns *a*, *a* on each machine are attached to a frame that has a vertical motion controlled by means of the crank *c*. The drag is placed over the patterns *a* on the machine shown in Fig. 15 (*a*) and rammed up, and in the same manner the cope is prepared on the machine shown in Fig. 15 (*b*). The patterns in each case are drawn downwards from the sand through the

stripping plates *b*, *b* by a suitable movement of the crank *c*. The two finished halves of the mold are then lifted from the machines, put together, and placed on the floor ready for pouring.

Such machines are made in a great variety of forms. By applying different draw-plates and stripping plates, these machines may be used for a large variety of work. The machines shown in the illustration are portable, being moved either by hand or by means of cranes.

15. Match Plates With Movable Patterns. There is a class of patterns having projections that make their withdrawal from the sand impossible without extra operations. This form of casting can generally be made in large quantities and with facility, either by hand in the usual way or on a molding machine, by making either the whole or a part of the pattern movable on a match plate. An example of a pattern of this class mounted on a suitable match board is shown in Fig. 16 (*a*), and the casting in Fig. 16 (*b*).



(*a*) (*b*)

FIG. 16.

It is impossible to withdraw this pattern from the sand if the part *a* is made in one piece with the standards *b*, *b*. It may, however, be molded successfully by making the pattern for the standards hollow and dividing the pin *a* in the middle of its length, as shown in Fig. 16 (*a*). By making the two parts of the pin movable, they can be pulled backwards into the recesses *c*, *c* by means of the rods *d*, *d*, and the pattern easily withdrawn from the sand.

A stripping plate arranged with two sets of movable patterns for sheaves is shown in Fig. 17. This method is adapted to molding circular and symmetrical castings, such

as wheels, sheaves, pulleys, disks, etc., having projecting parts that prevent the patterns being withdrawn in the usual way from the sand. A half pattern is necessary, the divisions being made along a diameter. The half patterns *a*, *a*, etc. are attached to rods *b*, *b*, and arranged on the stripping plate *f* so that the diameter of the patterns coincide with

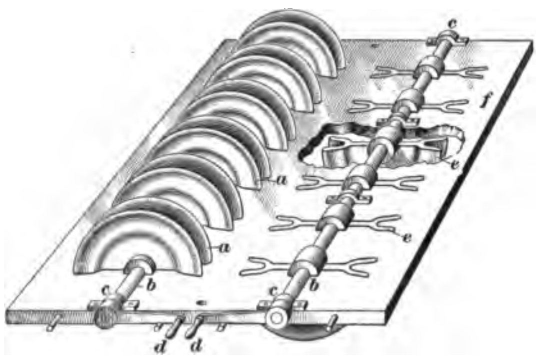


FIG. 17.

the surface of the plate. The openings in the stripping plate conform with the diametral section outline of the patterns. The rod is fastened to the plate by means of the bearings *c*, *c*. The drag is placed over the patterns and rammed up, and the patterns withdrawn through the plate by turning the cranks *d*, *d* on the ends of the rods. The illustration shows one set *e* of the patterns withdrawn. In like manner the cope is prepared, after which the two parts of the flask are fitted together and poured.

16. Match Boards With Removable Parts of Pattern.—An example of match-board molding in which part of the pattern is removable is shown in Fig. 18. The completed casting, a chain wheel of a pump, is shown in Fig. 18 (*a*), and the pattern *a*, match board *b*, bottom board *c*, and completed mold *d*, are shown in Fig. 18 (*b*). The pattern is made of brass, with the prongs *e*, *e* on one side removable and fitted with pins *f* in the usual way.

The solid part of the pattern is recessed into the match board to the parting line, as shown at *h*.

In making the mold, the complete pattern is fitted to the match board *b*, the loose parts being uppermost, and laid on the bottom board *c*, as shown. The cope is then placed over the match board and rammed up, turned over, and the match board lifted off, leaving the pattern in the cope; parting sand is put on the face of the mold in the cope, and the drag

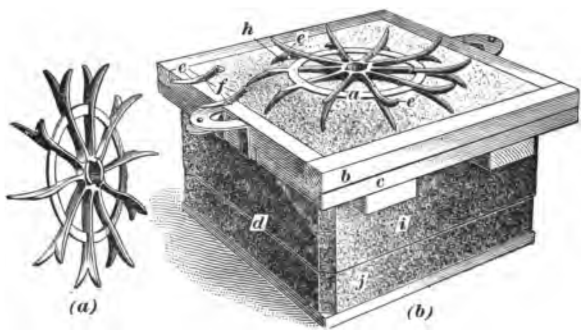


FIG. 18.

put on and rammed up. The mold is reversed and the cope with the detachable prongs *e* of the pattern lifted off; these prongs are then picked out by hand. The solid part of the pattern is removed from the drag, the two parts of the mold *i* and *j* placed together, and the snap flask removed, as shown in the illustration. The molds are made at the rate of one in 4 minutes for castings weighing about 2¼ pounds each.

17. Match Boards.—Match boards are made of wood, plaster of Paris, metal, or composition. When only a few castings are to be made, the molder will usually make the match of molding sand. Wooden match boards are often used, but they are expensive when the joint line is very irregular. Plaster of Paris is a material that is easily prepared and molded into match boards, but it is brittle and easily broken, will not bend, and cannot be repaired. Composition boards made of sand, boiled linseed oil, and litharge

are the cheapest and best. They are hard, tough, and elastic, not liable to shrink, swell, or crack, and repairs or alterations are easily made. The composition is made by tempering either parting or fine molding sand with boiled linseed oil and litharge to the right consistency for molding, as found by experience. After molding the match board, it is dried by means of a gentle heat in the core oven while still in contact with the pattern. By adding from two to three tablespoonfuls of litharge to each pint of oil, the drying is facilitated. The usual time required to dry a match board 1 inch thick is 12 hours.

18. Example of Multiple Molding.—The method of molding a lock tumbler, shown in full size in Fig. 19, is illustrated in Fig. 20. The tumblers weigh $3\frac{1}{8}$ pounds per hundred, and 56 are made in each mold. The molds may be rammed by hand or pressed, as in this case, in a machine; by the latter method the complete molds can be made at the rate of about 20 per hour. In Fig. 20 (*a*) is shown the arrangement of the bottom board *a*, match board *b*, two sets, or cards, of patterns *c*, and drag *d*, ready for the sand. The card patterns *c* are made of brass, and those for 28 tumblers are united to one gate runner *e*, as shown in (*a*), (*c*), and (*e*). The match board is of sand composition, as described in Art. **17**. In (*b*) is shown the drag after being rammed up; and (*c*) shows the drag turned over, the bottom and match boards removed, and the cope *g* in place. In (*d*) is shown the cope *g* rammed up with the sprues *h*, *h* for two cards of patterns; and (*e*) shows the flask opened for the purpose of drawing the card patterns *c*, *c*, these being drawn from the drag by means of the pins *i*, *i*, etc., shown in (*a*). In (*f*) is shown the completed mold on the bottom board *a*, with the snap flask removed, and ready for pouring.

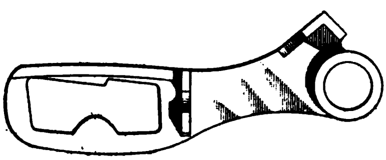


FIG. 19.

19. Gear-Molding Machines.—Gear-molding machines are used to make the molds for the teeth of gears.

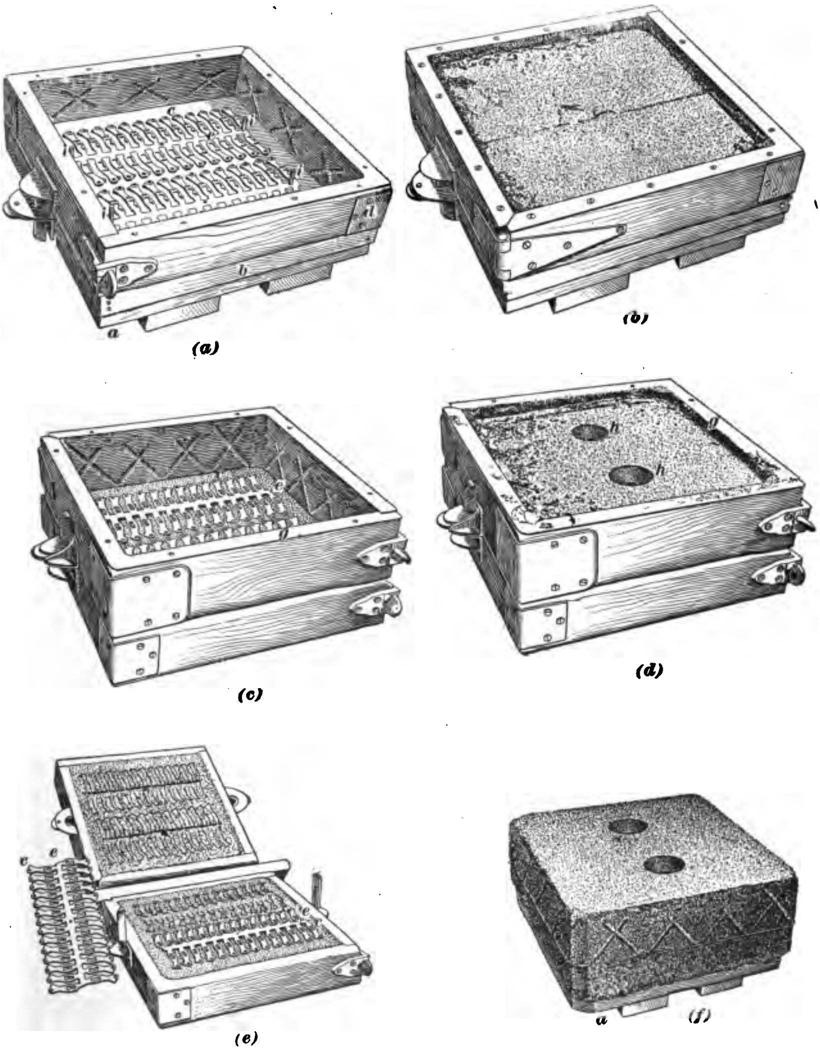


FIG. 20.

Fig. 21 shows one type of machine for this purpose, which is suitable for gears of the largest diameters. The base of

the machine rests on the bottom of the mold and supports a vertical column *a* in the center. This column carries an arm *b*, which revolves on the column *a*; it also has a horizontal movement and adjustment by means of the wheel *c* and a rack, and carries an indexing mechanism at one end. A vertically adjustable arm *d* carries at its lower end a pattern *e* for one or two teeth of the gear. The pattern is lowered to the required position for making the mold, and

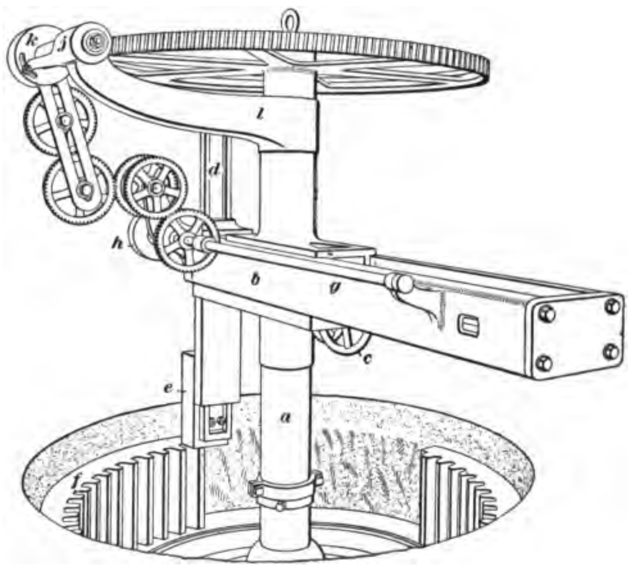


FIG. 21.

the length of the revolving arm *b* adjusted to give the diameter of the gear desired. The sand is rammed against the face of the pattern, as shown at *f*. The pattern is then withdrawn vertically from the mold, and the arm *b* supporting the pattern rotated forwards by means of the indexing mechanism the exact distance of another tooth or set of teeth, and the pattern lowered and the ramming process repeated. The indexing mechanism consists of a train of gears interposed between the shaft *g*, which is operated by a crank

revolving on the face of the index plate *h*, and the large stationary gear attached to the top of the column *a*. A worm in the case *j* meshes with the large gear and carries a gear on the end of its shaft in the case *k*, which receives motion from the train of gears extending to the shaft *g*. The arrangement is such that by revolving the shaft *g* by means of the crank, the arms *l* and *b*, which are attached together, are revolved on the column *a*. The index in each case must be set to divide the circumference of the gear into the number of equal parts to correspond with the number of settings required. The arms, ribs, and hubs of the gears are made with the aid of special patterns and placed in the molds after the machine has been removed.

A style of gear-molding machine suitable for smaller gears is shown in Fig. 22. The machine is mounted on a bedplate, and is stationary. It consists of a vertical column *a* carrying a revolving arm *b* that supports the pattern *c* for one or

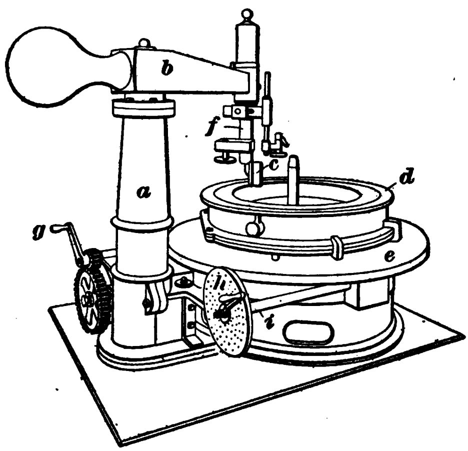


FIG. 22.

more teeth of the gear. The mold is prepared in a circular metal flask *d* resting on a revolving table *e*. After the pattern *c* has been placed in the mold and rammed up and withdrawn vertically, either by means of the slide *f* or the crank *g*, which operates a rack and raises or lowers the column *a*,

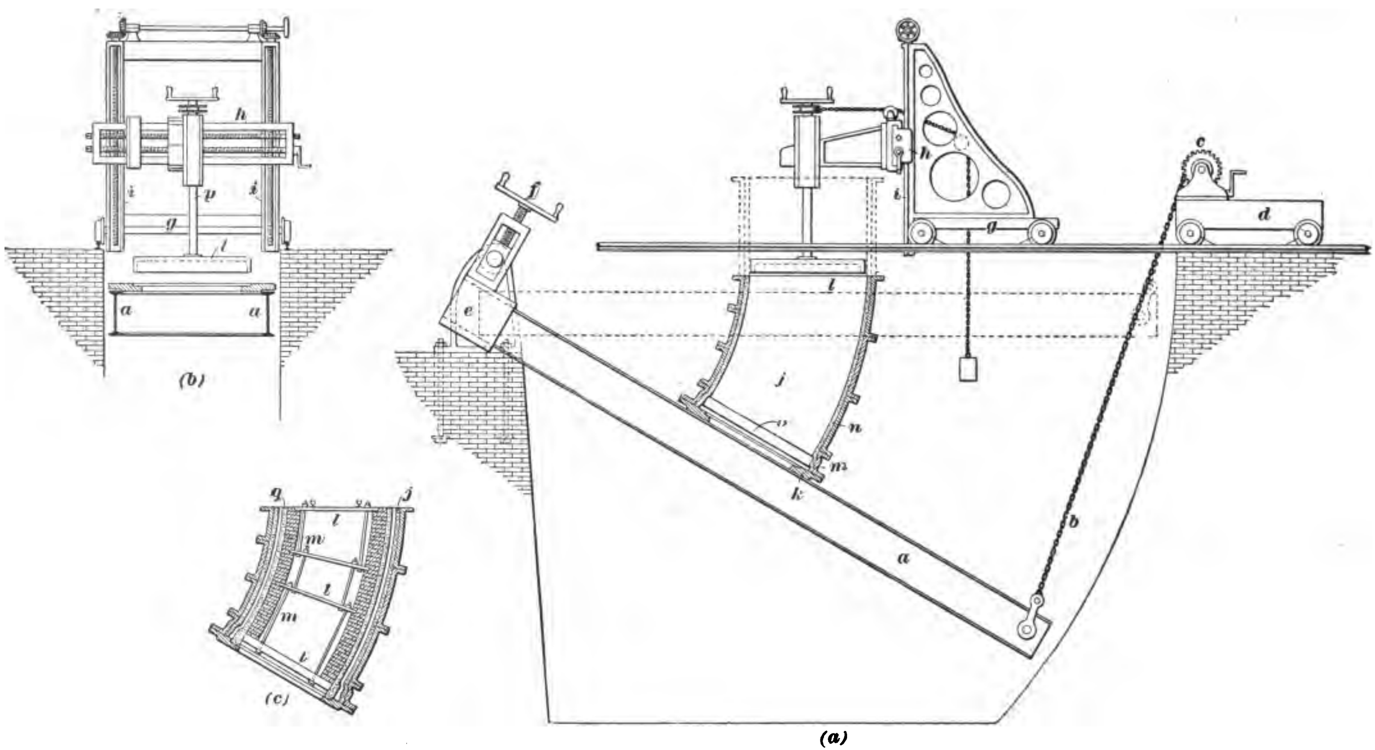


FIG. 23.

the mold is revolved the exact distance necessary to form the next tooth by means of the crank *h* of an indexing mechanism. The crank *h* is attached to the shaft *i*, which has a worm at the inner end that meshes with a rack on the under surface of the table *e*.

20. Molding Machine for Curved Pipes.—Fig. 23 (*a*) and (*b*) shows a design of molding machine for making curved pipes, which requires neither patterns nor core boxes, and has a capacity for making curved pipes up to 20 inches in diameter and of any desired curvature up to 50 feet radius and 60° in length. The machine consists of a frame *a* made of **I** beams, as shown in (*b*), which is hinged at one end so as to swing into a pit. The movable end of the frame is supported by a chain *b* whose length is controlled by means of a winch *c* on a car *d* that runs on tracks extending from the floor across the pit. The length of the frame *a* may be changed by sliding it through sleeves *e* that support it at the hinged end. The sleeves *e* have a vertical adjustment by means of a screw and hand wheel *f* attached to the bearing. A truck *g*, shown in Fig. 23 (*a*) and (*b*), runs on tracks over the pit and carries a cross-bar *h*, that has a vertical movement along two side posts *i*, *i* standing on the truck. The mold *j* for the curved pipe is started on a bottom plate *k* fastened on the frame *a* when it is horizontal, and the socket *o* is swept up by hand by the aid of a sweep *l* supported by the bar. After the socket is finished, the pattern *l* is used for the curved part. As the mold progresses, the frame *a* is gradually lowered at one end into the pit by means of the winch *c*. The flange or socket portion *m* of the flask is bolted to the bottom plate *k* and a section *n* of the flask bolted to the flange. The flask is made in several sections to facilitate ramming. As the ramming proceeds, the end of the frame is lowered by means of the winch, thus giving a mold of uniform curvature. The ends of the mold may be made straight by holding the frame *a* stationary and continuing the work by a vertical movement of the sweep or pattern *l*.

The core q for the mold j, as shown in Fig. 23 (c), is also formed on the frame a, but a ring is used for a sweep on the machine, instead of the disk l. The core is strengthened at the top and bottom and at suitable intervals by iron plates l that are bound together by iron rods m.

21. Machine for Molding Plowshares.—A machine for molding plowshares is shown in Fig. 24. Its construction is a radical departure from that adopted in other molding machines. The working parts of the machine operate hori-

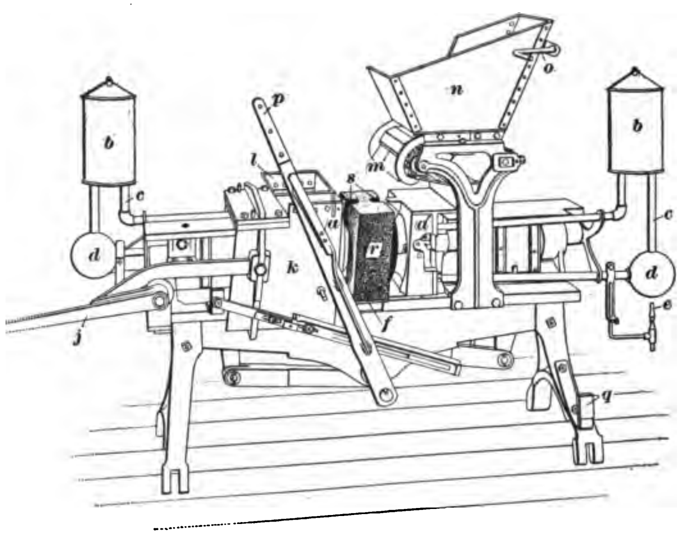


FIG. 24.

zontally. No flasks are used in forming or in handling the molds. The impressions in the sand are not made by patterns, but by specially shaped plunger heads, or matrices, a, a'. A special heating arrangement, consisting of tanks b, pipes c, heaters d, and gas jets e, keeps up a circulation of hot water in the plunger heads and prevents the sand sticking to the matrices. Fig. 25 shows both sides of a mold for a plowshare made on the machine shown in Fig. 24. Each mold has on one side the impression of the pattern corresponding to the

cope and on the other side that of the drag, half of the pouring gate *s* being in each side. The sand rests on a bottom plate *f*, shown in Figs. 24, 25, and 26. The molds are supported on the plates *f* on the rails *h*, shown in Fig. 26, of the frame on which the molds are placed for pouring. A plate *f* is placed in the machine, and a chill *i*, shown in Figs. 25 and 26, is laid against the proper part of the matrix. The lever *j* is raised and the mold box *k* moved toward the stationary matrix *a'*, which the box *k* slightly overlaps, and forms a flask to enclose sufficient sand for the mold. The hopper *l* is then under the outlet *m* of the large hopper *n*, which is supplied with sand by means of a conveyer. The operator turns the crank *o* until sufficient sand has been deposited in the mold, and then compresses the sand by moving the lever *p* from the position shown in Fig. 24 until it strikes the stop *q* on the leg of the machine. By reversing the levers *p* and *j* to the position shown in Fig. 24, the mold *r* is left in a position to be lifted from the machine by means of the bottom plate *f* and carried on the sling *t* of a trolley to the frame, as shown in Fig. 26. The projection *u*, shown in Fig. 25, is removed from the molds in the first row so that they will set squarely against a vertical end board *w*, shown in Fig. 26. The second row of molds is then placed against the first, the grooves *g* of the bottom plates *f* fitting projections on the carriage *v* on the rails *h* and making the molds match each other perfectly. The carriage *v* slides on the rails *h* and is used to adjust the molds so that they will match properly. The other rows are then set in place until the frame is filled. A board is placed across the end of the last row, similar to the one across the first row, and clamped to the frame so as to hold all the rows of molds securely together. After the molds are clamped together, they are all poured.

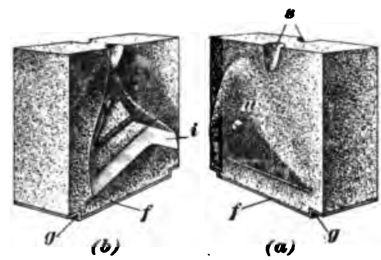


FIG. 25.

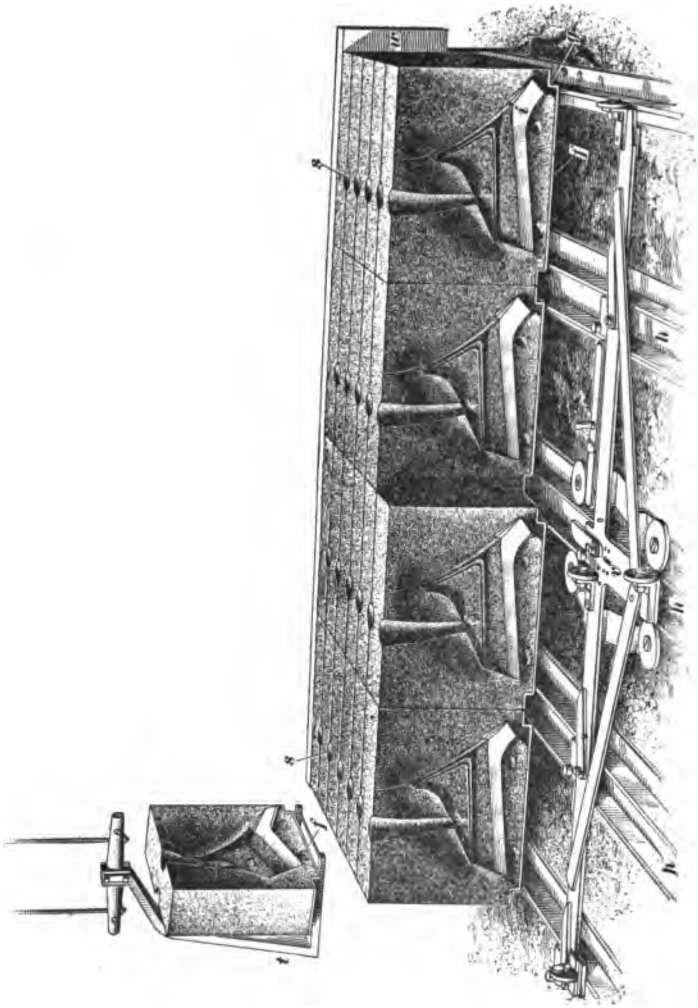


Fig. 26.

FOUNDRY APPLIANCES.

(PART 1.)

BUILDINGS, GROUNDS, AND EQUIPMENT.

BUILDINGS AND GROUNDS.

INTRODUCTION.

1. General Foundry Conditions.—It is impossible to lay down iron-clad rules prescribing the best arrangements and most suitable features for all foundries. The varying conditions imposed by competition in the matter of quality, quantity, and cost, and the nature of the work that comes within the scope of each individual plant, require that the methods adopted be those best suited to the plant under consideration; in many cases these methods will be very different. Equipments that give the best results in one case may prove failures in another. In giving the description of modern foundries and the various machines and systems that form a part of their equipment, it must be understood that much that is said is ideal in its nature. While the manufacturing foundry embraces the greatest number of the modern tendencies in founding operations, many of them apply to any foundry; but no two foundries have conditions exactly alike. From the many styles of buildings and the various appliances for foundry use, it is

necessary to figure out and arrange in each case those most suitable for the specialty to be manufactured; so that the designing of a modern foundry requires considerable experience and good judgment on the part of the engineer in charge.

2. Foundry Branches.—The equipment and operation of a foundry will depend on whether its castings are made of steel, malleable iron, gray iron, black iron, white metal, etc. They also depend on whether light or heavy castings are made, and whether it is a specialty or jobbing foundry. *Jobbing foundries* produce a great variety of castings, while *specialty foundries* make nothing out of the regular line of work for which they were originally equipped. Some of the gray-iron specialties are castings for rolling mills and heavy machinery, chilled-iron rolls, pipe, car wheels, car and railway fittings, air brakes, light machinery and machine tools, pumps, gears and pulleys, agricultural machinery, stoves, hardware, fittings, ornamental and art castings, electrical supplies, hollow ware, etc. A large portion of the heaviest class of molding is done in loam, and the remainder in either green or dry sand.

GENERAL ARRANGEMENT.

3. Location. — Foundries are preferably located in manufacturing centers and where the best and most convenient shipping facilities are afforded. When selecting a site, it should be taken into consideration that all the raw materials, as well as the finished and waste products, have considerable bulk and weight, and should be hauled the shortest distances and handled the least number of times in order to curtail general expenses. Freight charges for pig iron, scrap, coke, sand, limestone, and other supplies add considerable to their first cost; and the transportation charges for castings and slag must be added to the cost of the castings to determine their selling price. The foundry should be located near the source of supply of the raw materials, and, if possible, near where the greatest part of the product is consumed and the waste can be disposed of

at the lowest cost. Good distributing points are on navigable waterways and at railway intersections. It is always advisable to locate the foundry so as to have the advantage of several competing railways, and to have both land and water shipping facilities. All parts of the works should be directly accessible by railways, with the necessary switches and sidings; adequate wharfs are required on the waterways, and both systems should be equipped with the best arrangements for loading and unloading. A foundry plant consists of one or more buildings and a stock yard.

4. Extensions.—It is advisable to erect the foundry buildings on a tract of land that will not only permit extensions to be made, but also has a suitable area for a dumping ground for refuse, slag, and burned sand. A dumping ground is a great convenience, as it allows the immediate and rapid disposal of the waste products, but often the interest on the investment in a dumping ground is greater than the freight charges that would remove the waste a considerable distance.

5. Modern Tendencies in Foundry Building. Modern foundry buildings are substantial structures of brick and stone, with a framework of steel. They have complete systems for heating, lighting, and ventilating; also lavatories, wash rooms, lunch rooms, and other minor conveniences. Traveling cranes run the entire length of the foundry floor and stock yard, and hoists and jib cranes are liberally distributed.

6. Light for Foundries.—The principal work in the foundry consists in preparing the molds, which involves the greatest skill, is the most expensive part of the process, and requires the closest attention and the largest portion of the space of the entire foundry plant. The nature of the work of a molder is such that, even in the brightest daylight, it is often necessary to use artificial light. In the old-fashioned shop a torch was indispensable, but these have now been replaced, to a considerable extent, by portable incandescent electric lamps.

There should be the best possible natural light over the entire foundry floor. This requires large side windows and numerous skylights; or the space over the molding floor may be roofed with corrugated glass, which admits plenty of light without the glaring effect of direct sunlight. Translucent fabrics, which consist of a wire cloth embedded in a translucent material, are also used for foundry roofs. Dark nooks and corners should be avoided. But in addition to this, the foundry floor requires artificial illumination several hours each day during the winter months and in cloudy weather. For such days, and for night work, enclosed arc and incandescent lamps give the best illumination.

7. Heat and Ventilation.—One of the greatest contrasts between the old and the new foundry buildings is in their systems for heating and ventilating. Plants for heating and refrigeration are now so arranged that pure air of an agreeable temperature is supplied to the working rooms at all seasons; also the dust and smoke caused by the casting operations are rapidly removed. The same system of pipes and registers serves to deliver warm air in winter and cool air in summer.

BUILDINGS.

8. Arrangement.—The **foundry buildings** comprise a cupola house, molding and core departments, engine room, and repair shop. Large establishments have, in addition to these, a pattern shop, a pattern storage house, machine, blacksmith, and carpenter shops; and a warehouse, shipping department, and a laboratory, which are usually connected with the office building. The erecting shop, warehouse, and the sorting and shipping departments may form an annex to the other building, but the operations in the two buildings should be kept entirely separate from each other. The pattern storage house should be a fireproof structure, either an isolated building or a specially

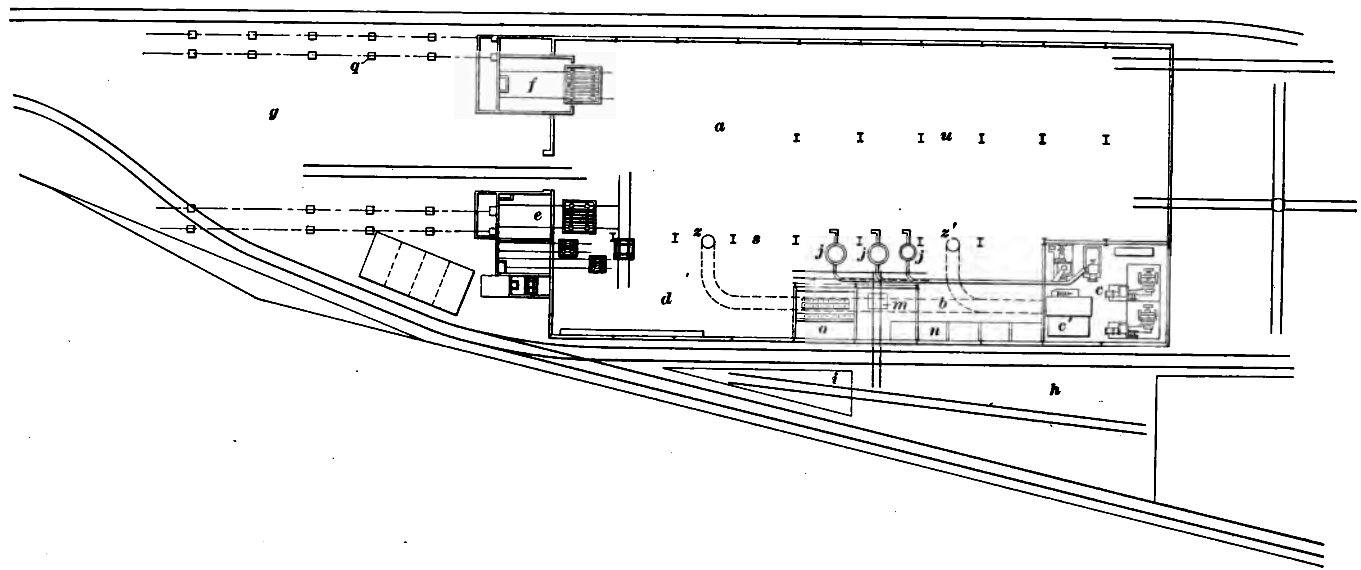


FIG. 1.

constructed room in one of the larger buildings. Special care should be taken of patterns used in founding, as they are generally the accumulation of many years of labor and invention, and cost a large amount of money. The loss of patterns in some cases would be irreparable. A convenient location for the pattern shop is between the molding department and the pattern storage house. The engine room, machine, and carpenter shops should be near one another, though if an electric system of power transmission is used, there may be some other convenient arrangement for them. The offices and laboratory adjoin each other and are best located in the front of the group of buildings, so as to make general access to the plant and its supervision as easy as possible.

9. Descriptions of Modern Foundry Buildings. While many foundries consist of only a single building, those doing extensive manufacturing have separate buildings for the different subdivisions of the work. In Fig. 1

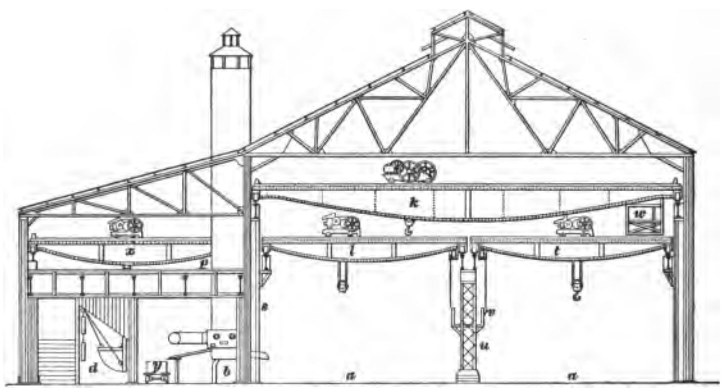


FIG. 2.

is shown the floor plan of a foundry building designed for making heavy castings, while a section across the building between the cupolas and the engine room is shown in Fig. 2. The molding floor *a*, Figs. 1 and 2, covers the main portion

of the building. In the lean-to are the cupola house *b*, engine room *c*, and core department *d*. The core ovens *e* and ovens *f* for drying molds are located at the end of the main building as annexes to it. As only heavy work is made in this foundry, the cleaning is done either on the floor *a* or in the yard *g*. The iron is stored in the yard at *h*, and the coke bins are at *i*, both being as near the cupolas as possible.

The three cupolas *j* are located in a row near one another, about the middle of one side of the molding floor. The melted iron flows from the cupolas into ladles, which are carried by either of the cranes *k* and *l* over the molding floor. The iron, coke, etc. for charging the cupolas are elevated to the charging platform for the cupolas by means of the hoist at *m*. The space *n* along the wall in the rear of the cupolas is used for bins for core and molding sands and for clay; the wash rooms *o* are also located near the cupolas. The hoist *m* for raising the iron, coke, etc. from the ground to the charging platform *p* is between the middle cupola and the wall. The large electrical traveling crane reaches entirely across the molding floor and is supported by runways that extend the full length of the building and also over the yard *g*; one of these cranes is shown at *k*. The foundations for the supports of the runways over the yard are shown at *q*. Along the cupola side of the building the track is supported on the row of columns *s*. Under the large crane *k* are two cranes *l* and *t* that are one-half its length. A central row of posts *u* extends down the molding floor for about half its length and supports the tracks for the inner end of each of the two shorter cranes *l* and *t*, which run under the large crane *k*. An elevated platform *v* on the row of posts *u* is used by the operator of the two small cranes, while the large crane is operated from an operator's cab *w* attached to it. A small crane *x* runs over the core department *d*. The slag and cinders are removed by means of a car *y* running on a track at the rear of the cupolas. The fan *c'* delivers fresh air to the foundry floor through the two conduits *z*, *z'*.

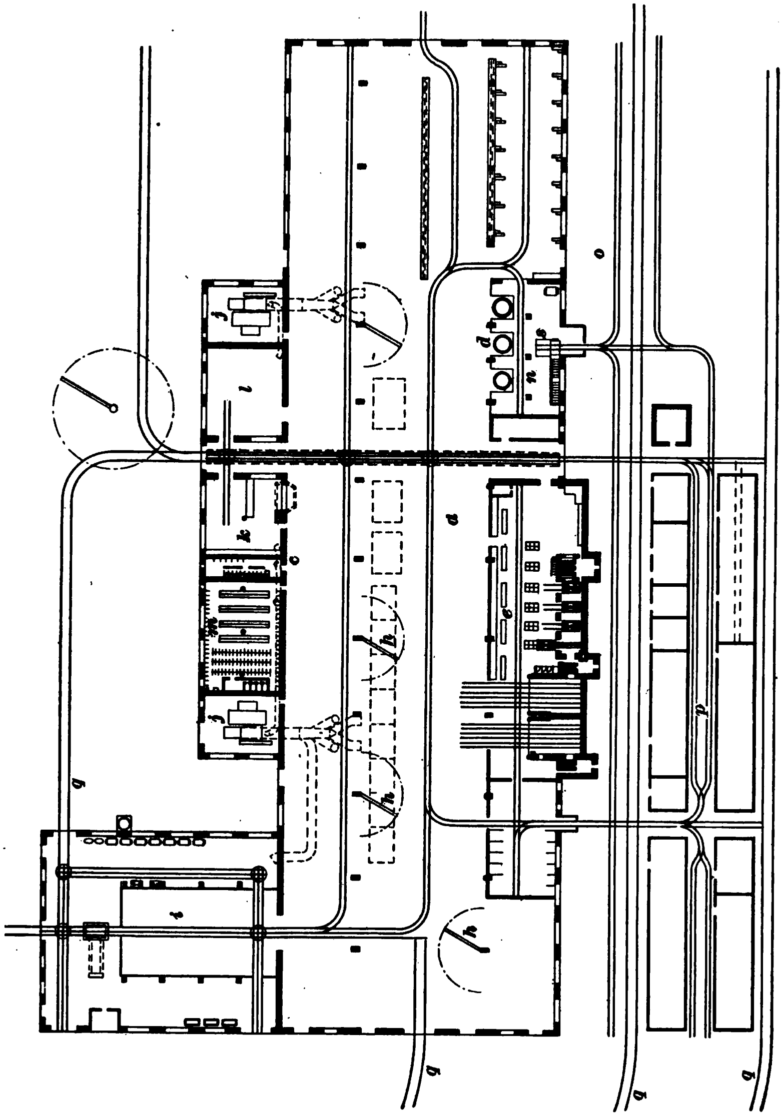


FIG. 3.

10. In Fig. 3 is shown the plan and in Fig. 4 a cross-section of a foundry building, which embraces not only the equipment necessary to nearly all small foundries but many appliances that are applicable to the manufacture of any of the classes of either light or heavy castings. The building consists of a main portion *a* with lean-tos *b*, *c* along each side, as shown in Fig. 4, these having various offsets and irregular shapes to provide the floor space necessary for the most convenient arrangement of the apparatus in the equipment. The cupolas *d* are located in the room *b* in a row along the side of the main molding floor; the core department *e* is located near the cupola room on the same side of the main floor. The building is lighted by large skylights in each roof and windows in the walls and gables, and in the space between the eaves of the main portion of the building and the top of the roof of the sheds. A large traveling crane *f*, Fig. 4, travels nearly the full length of the building, and a smaller traveling crane *g* is located in the lean-to *c*. Several jib cranes *h* operated by electric motors are located along the sides of the molding floor. These jib cranes are pivoted to the columns of the building in such a manner that they can be lifted off their supports and removed to other columns by means of the traveling crane. The cleaning department *i* is located in an annex at one corner of the building; and the heating and ventilating machinery *j*, *j*, the pattern room *k*, wood shop *l*, and lavatory and dressing rooms *m*, in additions against the lean-to *c*. The blower and air compressor are located on the second floor of the cupola room *n*. The yard *o* in the immediate vicinity of the cupolas is used for the storage of iron and coke, while that at *p* is occupied by sheds for the different kinds of sand and other molding materials. A narrow-gauge railway system extends throughout the whole plant, connecting the different departments and the stock yard with one another. Steam-road tracks *q*, *q* lead into the buildings and the stock yard. The stock is elevated to the charging platform *r* by means of a hoist *s* located at the rear of the cupolas.

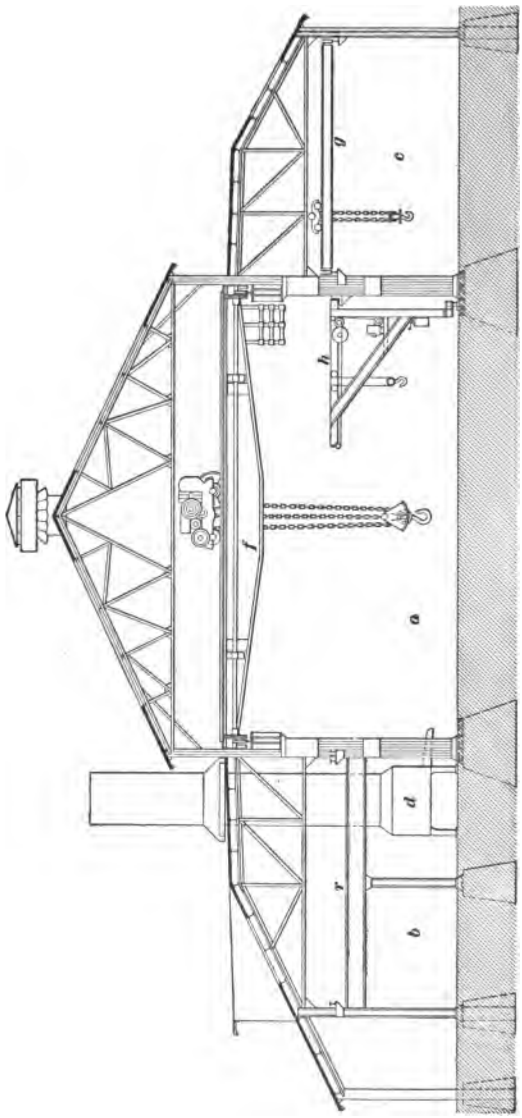


FIG. 4.

11. The **stock yard** is used for the storage of the various grades of pig iron, scrap iron, sprues, and coke; it should have bins and sheds for molding sand, firebrick, fireclay, facings, pattern and flask lumber and for storing flasks, hose, tools, and other supplies and miscellaneous materials that should not be exposed to the weather. In some cases it is most economical to store the iron, coke, and coal on a level with the charging platform of the cupola, which is usually from 12 to 15 feet above the floor of the foundry. This can be done by building the bins on a substantial elevated structure, which is provided with tracks connected by suitable inclines with the railway sidings. The materials are brought directly to the required height by the shifting engine that delivers the cars into the yard. Waterproof bins and sheds should be constructed under the upper yard and used for the storage of the supplies and appliances previously mentioned. Narrow-gauge tracks, from 30 to 36 inches (between rails), connect the upper storage bins with the charging platforms of the cupolas and the lower yard bins with the floor of the foundry.

The greatest possible care should be bestowed upon the construction and maintenance of the track systems and equipments, for smooth and well-laid tracks and substantial car trucks insure continuous and satisfactory service and minimize repairs and interruptions from breakdowns and derailments. A longer life of the structure is insured if it is not subjected to the shocks from wheels of heavily loaded cars passing over rail joints, frogs, and crossings. The narrow-gauge tracks are in almost constant use in foundries and the standard tracks must withstand very heavy loads; grade crossings of the two should not be tolerated. This can be done by arranging the upper bins between the two systems of tracks, with the narrow gauge next the building and the standard gauge on the far side. By the use of double-track bridges, turntables, and Y's, it is possible to reach all parts of the structure in the easiest and most direct manner and with the least delay in the service. The tracks should be so arranged that all loaded trucks will

move from the storage bins toward the cupola platform in the most direct line possible, and all the empties move in the opposite direction by a separate return track; the tracks should slope from the yard to the platform, and thus save labor in transporting the material to its destination. The most economical location for the sand bins is directly under the upper-yard stock bins. Sand should be shipped in cars with hopper bottoms, so that it can be dropped directly from the car into the bins. Coke and limestone require cars with side discharge, while gondolas are best for iron shipments, especially if cranes are used for unloading. The supply of sand should be secured during the summer, for the extra weight of wet sand increases the freight charges; besides sand shipped in winter is liable to be frozen, so that the unloading will require a greater outlay for wages. Careful foundry managers provide ample storage capacity and lay in a good supply of all necessary supplies in proper season ; also, track scales are provided so that all materials deposited or withdrawn may be weighed. It is generally best to enclose the stock yard and other portions of the ground, not surrounded by buildings, by a substantial fence.

EQUIPMENT.

DESCRIPTION OF APPLIANCES.

12. Location of Cupolas and Charging Floors. The ideal location for the cupola is in the center of the molding floor; but this requires extensive grounds and track systems with long approaches to be really serviceable, as the railway tracks near the end of the building are on an inclined trestle and the coal, coke, and iron are delivered by the shifting engine directly to the cupola-charging platforms, which are sufficiently large to store a liberal supply of materials. In an arrangement of this kind the elevated platforms, or cupola top house, are over part of the molding floor. Foundries not having the necessary ground for this center

arrangement of the cupolas are equipped with elevators that convey the materials from the ground level to the cupola charging platforms. The next best position for the cupolas is midway along the side of the molding floor. This plan makes it possible to convey the materials from the upper bins outside the foundry to the charging platforms or to use elevators to handle the materials from the lower yard. With the cupolas at the side, the slag and refuse are easily accessible from the outside and can be removed without inconvenience to the molders.

In Fig. 5 is shown the plan of a charging platform where the cupolas are located near each other along the side of the

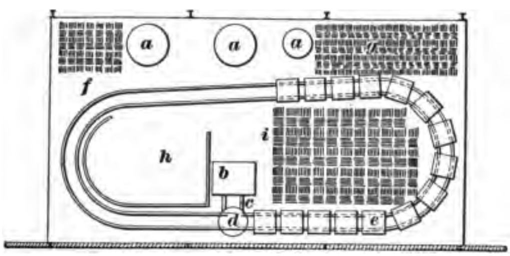


FIG. 5.

molding floor, while Fig. 6 shows the general arrangement of the appliances and materials on the platform. In this case all the stock for charging the cupolas *a*, *a* is brought to the floor by means of a hoist *b*, operated by an electric motor. A narrow-gauge track *c* leads from the hoist to the turntable *d*, which permits the trucks *e* to pass from the hoist to the elliptical-shaped track that extends around the floor. This track is long enough to hold a train of trucks with all the coke, iron, etc. required to charge the cupola for a day. The trucks pass by the cupolas and the materials are charged directly from them, thus necessitating a minimum of handling. A quantity of pig iron and scrap is stored at *f*, *g*, and *i* and coke at *h* to supply the cupolas for a short time in an emergency, such as the stoppage of the hoist, or an accident to the trucks in the yard, etc.

If more than one cupola is used, it is sometimes of advantage to place them far enough apart so that each will command an equal portion of the molding floor. This, however,

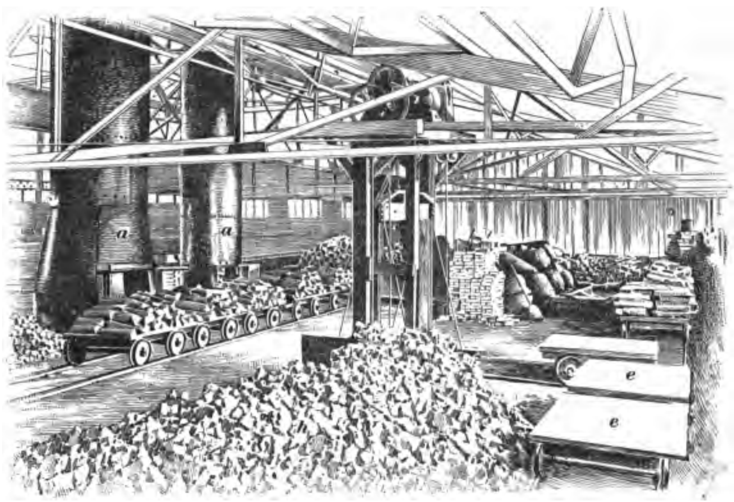


FIG. 6.

depends on the general nature of the work and is less convenient in foundries where the metal from two or more cupolas is used for single large castings.

13. Blowers and Fans.—The blast is furnished to the cupolas by **blowers,** which may be *positive* or *non-positive* in character; the former forces a constant volume of air into the cupola, while the latter furnishes air at a constant pressure but does not necessarily deliver a constant volume into the cupola. A **positive rotary blower** is shown in Fig. 7 (*a*) and (*b*). The machine is driven by a belt on the pulley *a* on the shaft *d*, as shown in Fig. 7 (*b*), which is a vertical cross-section through the middle of the blower; gears covered by the casings *b* connect the upper shaft *c* with the lower shaft *d*. The impellers, or vanes, *e*, *f* are keyed on the shafts *c*, *d*, and in rotating within the casing *g*

in the direction of the arrows, draw the air in at *h* and discharge it at *i*. The impellers are constructed

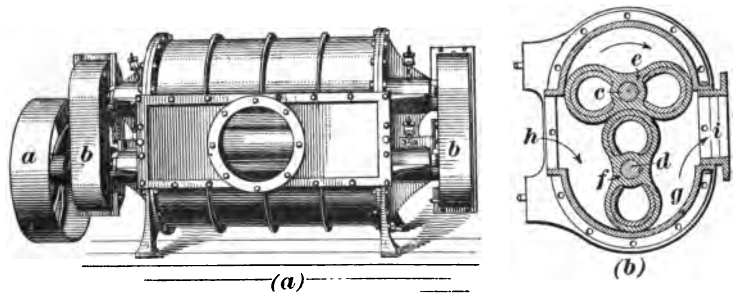


FIG. 7.

so as to have a close working fit with one another and with the casing. When revolving they are kept in their proper relative positions by the gears that connect the two shafts.

A **non-positive blower, or fan,** as it is commonly called, is shown in Fig. 8. The casing *a* encloses a fan wheel made of a number of straight or curved vanes fastened to the arms of the spider, which is keyed to the drivingshaft *b*. The rapidly revolving fan wheel draws in the air through the central opening *c* and discharges it at the outlet *d*, whence it is conveyed through a suitable pipe to the cupola. Blowers and fans are frequently operated by direct-connected engines or electric motors. With a fan blower, the volume of the air is automatically increased as the resistance to the flow of the air is decreased, and vice versa.

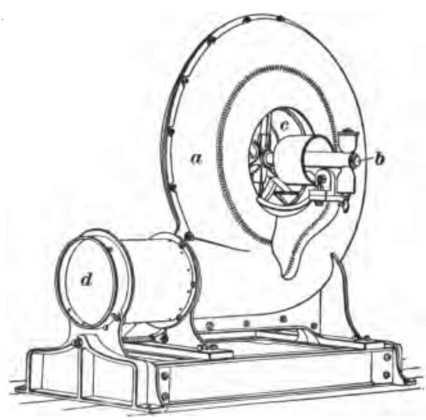


FIG. 8.

Blowers and fans should have solid foundations and should be located near the cupola, as the farther away they are, the more power is lost by friction in the pipes. The loss of pressure in the pipes increases directly as the length of the pipe and as the square of the velocity of the air. The combined areas of branch pipes should be somewhat greater than that of the main pipe from which they lead, and the area of all pipes should increase as the distance from the blower increases. If the diameter of the blower outlet is 3 inches, that of the pipe at 30 feet should be $3\frac{1}{4}$ inches, and at 300 feet $5\frac{1}{2}$ inches. In erecting air pipes the least possible number of elbows or turns should be used, and these should be rounded, as square turns greatly retard the flow of the air. Sudden changes in the diameter of the blast pipe should be avoided. If it is necessary to reduce or enlarge the diameter of the pipe, this should be done with a special tapered section. Special care must be taken to have all joints air-tight. The distance between the blower and the cupola should be such that the blast pipe will serve as a reservoir of sufficient capacity to provide for the irregularities in the service. From 30 to 40 times its diameter is a good length for the blast pipe. The melting process in a cupola requires about 30,000 cubic feet, or about 3,000 pounds of air per ton of metal melted. If the tuyeres of a cupola become stopped when a fan is used to furnish the blast, the fan will cease to drive air into the cupola, but the pressure of the blast will not rise and give an indication of the difficulty. If a positive blower is used and the tuyeres become stopped, the pressure of the blast will rise until the obstruction is forced out of the way or until some weak part of the pipe system gives way.

14. Traveling Cranes.— The molding departments of large foundries are usually equipped with one or more overhead **traveling cranes** with runways extending the entire length of the molding floor; they are usually operated either by hand, electricity, or compressed air. Except in foundries where only light work is made, they prove

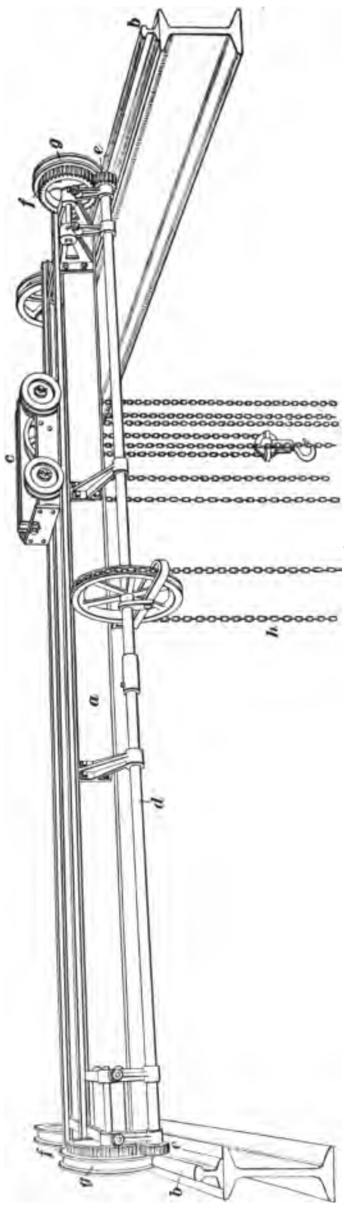


FIG. 9.

excellent labor savers. One style of hand-operated traveling crane is shown in Fig. 9. Such cranes usually consist of a bridge *a* extending across the foundry floor and resting on trucks at each end, which are supported by tracks *b* on the side walls or girders of the building. The bridge is operated from the floor by hand by means of a chain *h* that runs on a chain wheel on the shaft *d*; this shaft has a pinion *e* at each end that meshes with the gears *f*, *f*, which are keyed to the same shaft as the wheels *g*, *g* that rest on the track. When the shaft *d* is rotated by pulling the endless chain *h*, the crane is moved along the tracks *b*. A car *c* carrying the hoisting apparatus is arranged to travel along the bridge. Hand cranes are also operated by means of cranks and gearing on a stage suspended below one end of the bridge.

Where heavy work is to be done, electric or air motors are used to operate the cranes. An electric crane suitable for heavy work is shown in Fig. 10. The

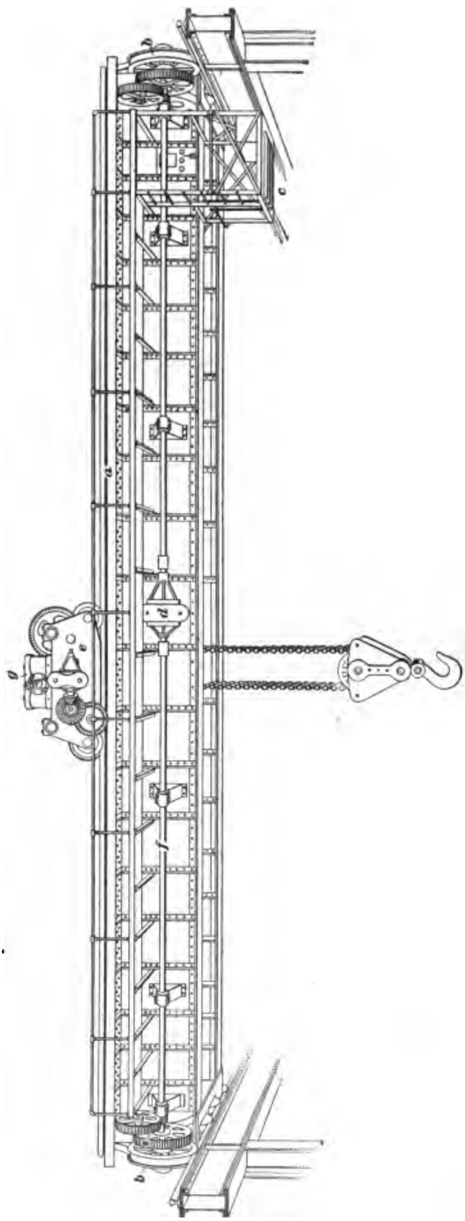


FIG. 10.

bridge *a* is made of two heavy steel-plate girders resting on a four-wheeled truck *b* at each end, which travel on tracks supported by the side walls of the building. An operator's cab *c* is attached to the bridge and is suspended under it at the side of the building opposite the cupola. The operator controls the motor *d* for moving the bridge along the length of the building, and the motors for moving the car *e* across the bridge and the vertical movement of the hoist. The motor *d* is located near the middle of the bridge and operates the shaft *f* that transmits the power to the gearing on the trucks *b* and causes the bridge to move along the tracks.

A motor *g* traverses the car *e* back and forth across the bridge. Some of the largest traveling cranes are provided with more than one car. The hoisting apparatus on the car may be direct acting for light work, and differential, duplex, or triplex acting for heavy service, though the car may be equipped with more than one hoist; a slow motion, for lifting heavy loads and a quick-acting hoist for lifting light loads, tilting heavy ladles when pouring castings, etc.

In order to prevent one end of the crane from lagging behind the other, it is important that the power be applied at or near the middle of the driving shaft *f*, unless some other provision is made in the design of the crane to prevent this difficulty. If the power is applied at the middle of the shaft, the torsion in the two parts will be as nearly equal as possible and thus tend to keep the bridge square with the tracks, thus reducing the friction and the power required to drive it. It is also necessary to place the load as near the middle of the bridge as possible, as a heavy load at one end will tend to make that end lag behind the other. The tracks of the runways should be kept in good alinement.

The apparatus for hoisting and moving the bridge should be started very gradually; sudden changes of motion should never be made, for serious accidents have been caused by rapidly changing the motion of the bridge, especially when it is loaded at one end. When started suddenly, there is a tendency for the loaded end of the bridge to lag behind and the other end to leave the track and fall to the floor; accidents of this kind have resulted in the loss of life and considerable property. Care should also be taken not to load the crane beyond its capacity, and to use each appliance for the purpose for which it is designed. It is not proper, for example, to use a heavy and slow-acting crane to handle light work that is to be lifted and transported within a limited and prescribed area. Such work is more economically done by the use of hand cranes, as previously mentioned, or by jib cranes, or pneumatic hoists.

15. A **jib crane** suitable for light work is shown in Fig. 11. Such a crane consists of a post *a*, pivoted at the top and bottom, and carrying a jib *b*. Sometimes both of the pivot plates are supported by one of the side columns of the building. A brace *c* supports the outer end of the jib. A trolley *d* carrying a chain hoist *l* is shown on the jib. The

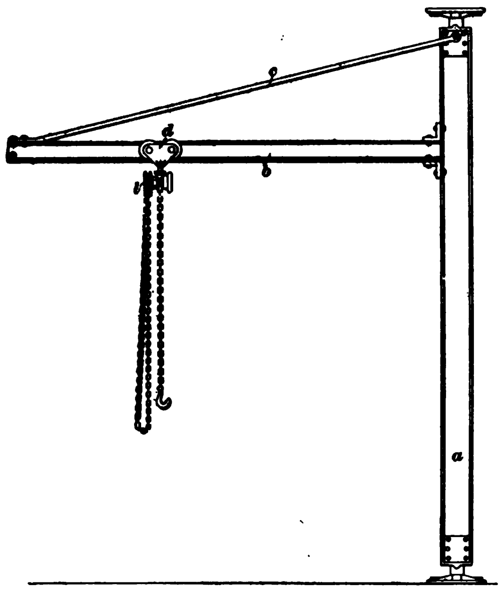


FIG. 11.

trolley *d* is also frequently equipped with a pneumatic hoist. Cranes of this type are usually secured to the columns of the building at the side of the molding floor, as shown in Fig. 4, and are designed to swing freely under the traveling crane; or they may occupy the whole space where no traveling crane is used.

In Fig. 12 is shown a jib crane for heavy service. The frame is made of steel and braced in a very substantial manner. The post *a* is formed of two channel bars stiffened by lattice braces riveted across the sides as shown. The jib *b* is made of two heavy girders separated far enough to

form a track for the carriage *c*, and to allow enough clearance between the girders for the vertical movement of the hoisting chain. The winch *e* for lifting the loads by means of the hook *f* is attached to the post *a* near the bottom so as to be conveniently operated from the floor by means of two hand cranks *g*, *g*. The movement of the carriage along the jib is controlled from the floor by means of a hand chain *d*

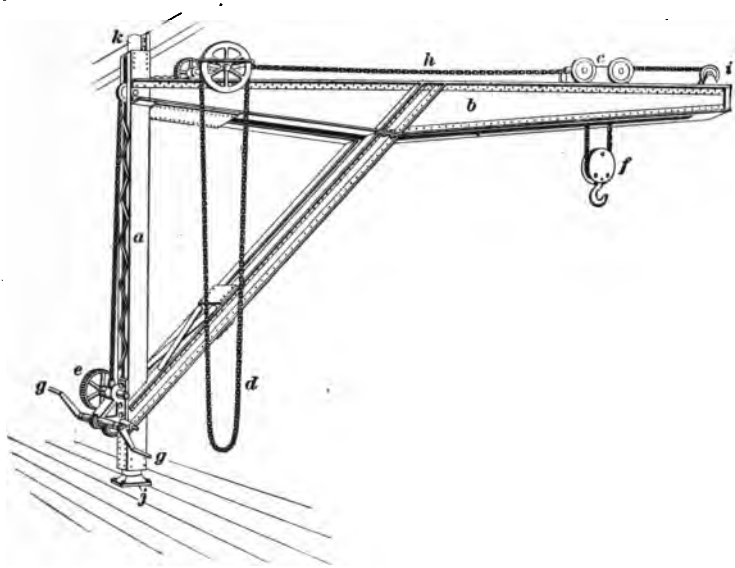


FIG. 12.

that operates the gearing on top of the jib at the end next to the post. The arrangement is such that an endless chain *h*, which is attached to the carriage *c*, passes around the wheel *i* at the outer end of the jib and a driving wheel that receives its motion from the power applied to the hand chain *d*; the carriage is moved backwards or forwards at the will of the operator. Electric or air motors or steam engines are often used both for operating the winch and the carriage.

The plate *j* on which the post *a* is pivoted should be supported by a substantial foundation. The upper pivot *k* is usually secured to one or more of the braces of the building.

16. Chain Hoists.—There is a great variety of hoisting appliances applicable to crane and trolley work. Some style of pulley block, which may be either of the differential, duplex, or triplex form and which will support the load in any position without the continuous application of power, is generally used; these are operated by hand, compressed air, or electricity. They may be attached to a crane or trolley simply by means of a hook, which is the case when a special trolley carriage is used, and also for light service. In Fig. 13 is shown a combined triplex hoist and trolley, which is a style frequently used.

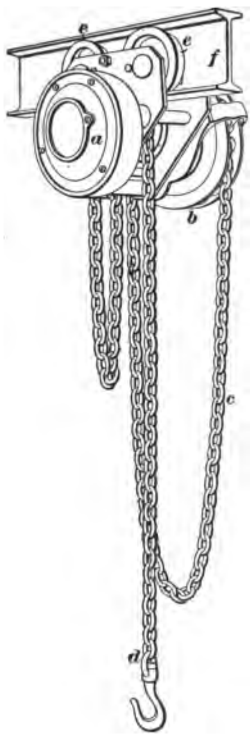


FIG. 13.

The hoisting mechanism of a triplex pulley block consists of a direct train of spur gears enclosed in the circular frame *a* and operated by means of a wheel *b* carrying a hand chain *c*. The gearing gives motion to a drum, which moves the chain *d* that supports the weight. The trolley is provided with four truck wheels *e*, two on each side of the track *f*. In the plain form, as shown in the illustration, the movement of the trolley is effected by pushing horizontally against the load in the direction desired; for heavier work, a geared trolley is used, which is moved by means of an endless chain passing over a wheel geared to the wheels of the truck.

It is customary to use chains for hoisting purposes, but they often cause slight irregularities and shocks, which are objectionable when lifting copes, withdrawing patterns, or setting cores. For these reasons wire ropes are preferable, as they work smoother; defects in steel ropes are more easily detected by superficial inspection than defects in chains. To insure safety, crane chains, hooks, and slings

should be inspected frequently and annealed at least once a year.

17. An **air hoist** is a serviceable appliance that can be used when compressed air is available. Such hoists are simple in construction, light in weight, occupy little space, are easily operated, and are not so likely to shake the sand out of copes as chain hoists. One form of air hoist is shown in Fig. 14 and consists of a cylinder *a*, in which there is a piston that supports the piston rod and the load on the hook *b* on the end of the piston rod. The compressed air is conducted to the hoist through a hose attached to a pipe at *c*; a valve *d* in the pipe at the lower end of the cylinder controls the admission of the air to and its exhaust from the cylinder and is operated by hand by means of the chains *e*, *e* and handle *f*. An air hose is more or less objectionable when it hangs down in the way of the workmen, and automatic reels and other contrivances are sometimes used to carry the slack hose. Such hoists may be stationary or portable; the latter style is suspended either by a hook that enters the ring *g*, or on trunnions *j* that rest on the carriage *h* that runs on a track *i*, as shown in the illustration. The latter form gives more room over the molding floor.

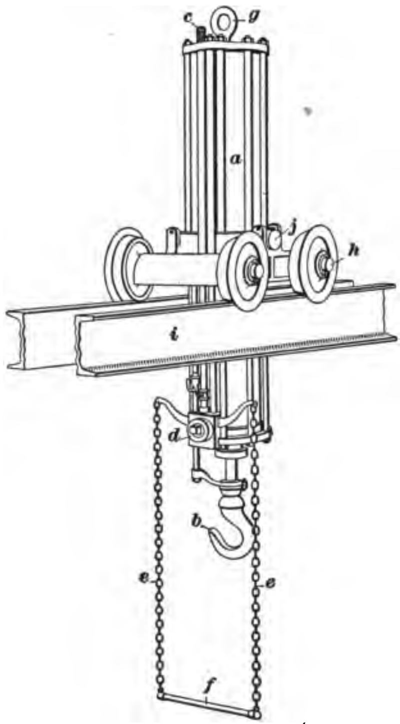


FIG. 14.

A *screw-governed air hoist*, shown in Fig. 15, is sometimes used in foundry work, as it is easily controlled and will support a load in perfect safety in any position within the length of its stroke. It works smoothly and can be delicately adjusted, and is therefore useful for lifting copes, drawing patterns, and setting cores. The air is admitted to and exhausted from the cylinder by means of a valve *a* at the lower end of the cylinder *b*, which is operated by a cord *c*. It requires a slight movement of the hand chain *d* to start the load either up or down. For light loads it can be worked without air pressure as an ordinary screw hoist. The motion is transmitted from the hand chain through the bevel gears *e*, *f*. The small gear *f* is on the end of the screw *g*, which extends into the hollow piston rod *h*, and the rotation of the gear causes the screw *g* to turn in the piston nut *i* and either raises or lowers the hook *j*, depending on the direction the power is applied to the chain *d*. This is really a screw hoist in which most or all of the load is supported by the compressed air during hoisting. If the load is left hanging on the hook, it will not lower if some of the compressed air leaks out.

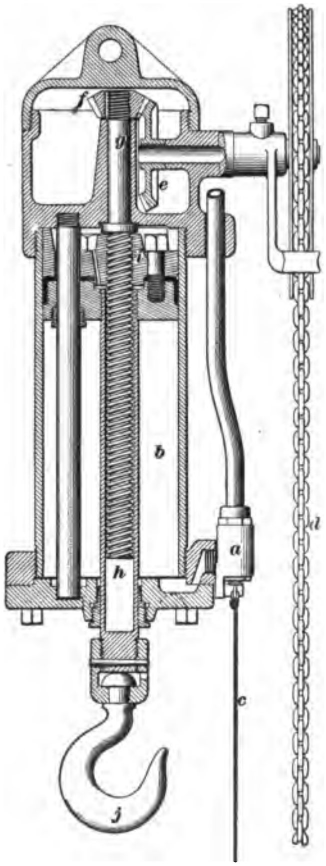


FIG. 15.

18. Trolleys.—Overhead trolley systems are frequently used instead of cranes. They possess many advantages for

handling light and medium work up to 1,500 or 2,000 pounds. They can be arranged to cover a large area; the devices are

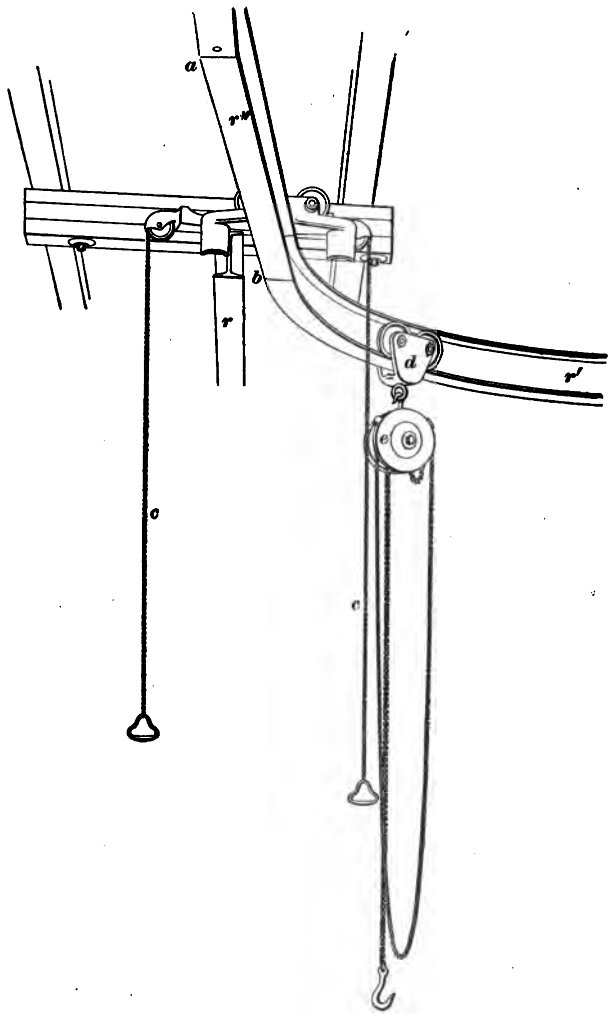


FIG. 16.

easily handled and several trolleys can be used on the same track at the same time without interference. The

tracks can be erected so as to join two or more departments of the foundry and the system may comprise a single track with switches or a double track with or without crossovers.

FIG. 17.

They are very serviceable for use over side floors where not obstructed by overhead traveling cranes, and can be suspended from the roof trusses, or in a variety of ways suited to all conditions. As the tracks cannot be supported

under traveling cranes without erecting posts on the floor, it is best under these circumstances to keep the tracks near the walls and secure them to brackets attached to the main columns of the building. The tracks are made of channels, I beams, or flat bars. The switches and crossovers must be designed so as to insure a continuity of the runway, and with no possibility of remaining open and dropping the trolleys. The trolley carriage for the flat-bar track may be simpler than any other style, having either one or two rollers as a support, but the double form running on I beams or channels is more substantial.

Fig. 16 shows a single-rail trolley system with a switch to carry the trolley from the main track to a side track. The portion of the track between *a* and *b* is hinged at *a* and serves as a switch. Its position is regulated from the floor by means of the chains *c*, *c*, so that either the main track *r* or the side track *r'* may become continuous with the switch rail *r''* as desired. The trolley is shown at *d* supporting a chain hoist *e*; pneumatic hoists are frequently used instead of chain hoists. The switch *r''* is provided with projections, one of which is always opposite the open end of the track so as to prevent a trolley running off the end of the track. One of these projections is shown at the end of the open track *r*.

In Fig. 17 is shown a double-track trolley system using crossovers, one of which is shown at *g*, for the purpose of changing the trolleys from either track to the other. The switch is operated from the floor by means of chains *b* that pass over a pulley *c*. A duplicate operating pulley *d* is arranged at the other end of the crossover for convenience. This system allows the use of several trolleys *a* on the tracks at the same time without interfering with one another, as shown in Fig. 18. The trolley ladles *b*, *b* pass under the spout of the cupola *c*, and after receiving the melted iron, change from the track *d* in front of the cupola by means of any one of the several switches *e*, *e* to some one of the main tracks *f*, *f* and are taken to the floor where the molds are to be poured.

The trolley *a*, Fig. 18, suitable for carrying large ladles, consists of four wheels *g*, *g*, two on each side of the **I** beam, held in place by a frame *h* that supports the ladle. There is a heavy coil spring in the sockets at each end of the frame *h*; the load rests on the springs, which prevent vibration and make the carriage smooth running. In Fig. 17 is shown an important application of the trolley system. A large ladle *e* of molten iron is brought from the

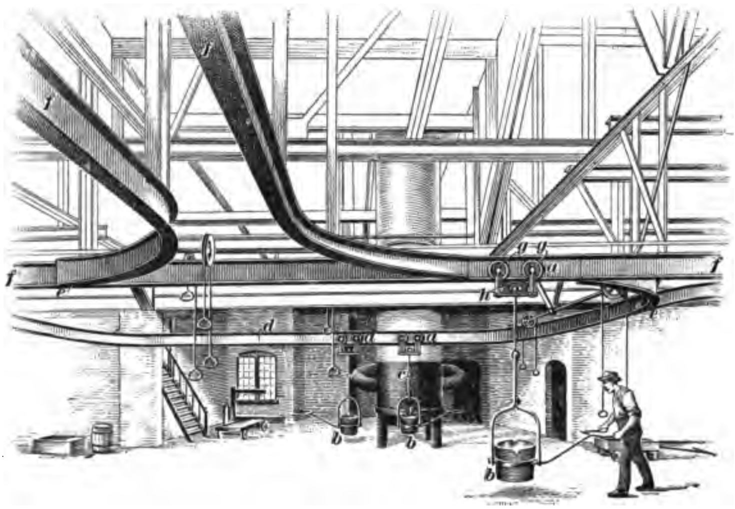


FIG. 18.

cupola to the place where the pouring is to be done and hand ladles *f* are filled from it for the purpose of pouring light castings on that immediate portion of the floor. This plan aids in keeping the iron hot for the work. By using the crossover *g*, the trolley ladle returns on the other rail to the cupola and leaves the way clear on the outgoing rail for other ladles to reach the same part of the floor.

A single flat bar set on edge is sometimes used for a trolley track, especially for light work. The carriage in this case may have either one or two wheels with the necessary frame and attachments for supporting the load.

19. Automatic electric trolley systems, or **telphers,** are used in foundries for conveying materials in the departments and from one building to another. They are serviceable for delivering castings from the molding floor to the cleaning room, the storeroom, or the shipping department. These telphers are operated from the floor by an electric switch. They run on overhead wire cables or tracks, over curves and switches, and in either direction; they can be arranged also to run on the surface or underground with equal facility. The car runs to its destination, the bucket trips and returns automatically. The equipment requires very little skill to operate it and its use greatly reduces the manual labor in handling materials.

20. Sand Conveyers.—In ordinary sand molding, either in flasks or bedding in the sand, molds are poured and shaken out at or very near the place they are made. In such cases the sand is usually tempered by hand and used over again. From time to time some of the worst burned sand is rejected, taken away, and fresh sand brought to take its place. When lighter or finer grades of work are made, where many cores or a great many nails or irons are used, the preparing of the sand becomes a serious item of expense and hence various systems of *conveyers* and machines for preparing the sand have come into use. This is especially true in shops where many duplicate small molds must be made. In general it may be stated that as the percentage of time required to prepare the sand compared with the time it takes to make the mold increases, the saving effected by mechanical devices for preparing the sand will increase.

In some cases it may be found advantageous to use an automatic trolley system to distribute molding sand. This may prove economical in foundries where bench molding at stationary benches predominates, but generally a more elaborate system of sand conveyers is used. A complete system for molding-sand distribution comprises an underground conveyer for taking the sand from the place where the molds are shaken out, a crusher, a mixer, a magnetic separator, a sifter, a temperer, an elevator, and an overhead conveyer

with distributing chutes and valves for returning the sand to the molding floor. It is rather difficult to design on an elaborate scale a sand conveyer that will be entirely satisfactory in operation, for the abrasive action of the sand soon destroys many of the details and impairs the efficiency of the system. Steel ropes and chains are not suitable for use in such conveyers, as they will soon be cut through by the sand.

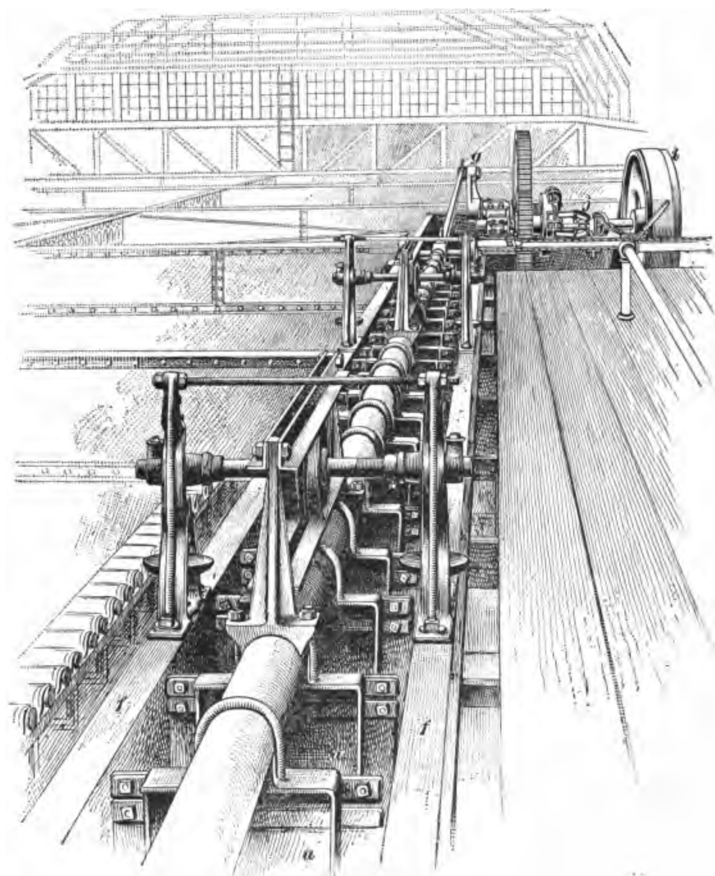


FIG. 19.

Sand conveyers of the **reciprocating type,** illustrated in Fig. 19, have given the best satisfaction in foundry

practice. They are simple in construction and the parts are not subjected to much destructive wear. Fig. 20 shows a longitudinal sectional view of an overhead sand conveyer, which consists of a series of wooden or steel blades *a* suspended from a tubular bar *b* by means of hinged connections *c*. The hinged joints are so constructed that they will not allow any movement of the blades back of a vertical position.

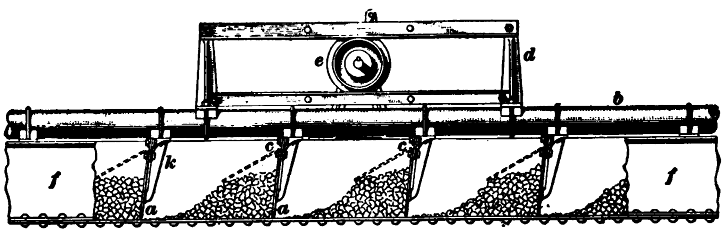


FIG. 20.

The tube is supported by angle-iron brackets *d*, each enclosing a flat-faced roller *e*, which allows a horizontal movement of the bar of from 3 to 4 feet. The bearings for the roller shafts are supported on the edges of the trough *f* in which the sand is conveyed. The blades are suspended in a trough *f* that receives the sand from an elevator. The bar is given a reciprocating motion by a crank *g* on the driving shaft, as shown in Fig. 19. The conveyer is driven from a belt on the pulley *i* and is stopped and started by means of the friction clutch *j*. The blades are held rigid during the forward motion by the supports *k*, Fig. 20, the bottoms being slightly in advance of the upper edges, and push the sand along the trough. During the backward motion, the blades lift upwards as indicated by the dotted lines and slide over the sand, dropping down behind the piles of sand formed in the forward stroke, and the forward motion is repeated. Openings with suitable valves and chutes are arranged in the bottom of the trough in places where the sand is needed. The oscillating system admits of great flexibility. The sand may be carried forwards in one or more main conveyers to branch conveyers, which deliver it to all parts of the molding floor.

21. In addition to the reciprocating conveyer illustrated in Figs. 19 and 20, a **rubber-belt conveyer** is frequently used. This consists of a rubber belt supported on pulleys in such a manner as to cause the belt to assume a trough shape. This may be accomplished by having one set of pulleys supporting the center and two sets of inclined pulleys placed in such a way as to support the outside edges of the belt. Such a belt is subject to less wear than a reciprocating conveyer and has a very great capacity, on account of the fact that both the sand and the conveyer are constantly moving forwards, hence the great loss of energy necessary to overcome the inertia of the reciprocating parts of the conveyer and to start and stop the sand is avoided.

The disadvantage of this style of conveyer is that it must deliver the material which it conveys at some stated point, either at the end of the conveyer or by means of a special side discharge at some point along its line. The reciprocating conveyer can be made to fill a series of pockets or hoppers. All the sand will fall into the first hopper until it is full, after which the conveyer will simply scrape the sand across the top of this hopper to the next, and so on. By having a discharge opening beyond the last hopper through which the sand falls after all the hoppers are full, the operator can see immediately when all the hoppers are full and stop the conveyer and the elevator that supplies it. This gives him but a single point to watch in order to control the system, while if a rubber-belt conveyer is used with an automatic arrangement for discharging into any one of the hoppers, it is necessary to observe each hopper separately, so that the apparatus requires considerable personal attention. Rubber-belt conveyers are especially applicable as main-line conveyers for supplying branch conveyers of the reciprocating type.

22. Sand Sifters.—New molding sand contains more or less gravel and vegetable matter, which must be removed before mixing. Sand that has been used generally contains

nails, gaggers, shot, iron, and fins. Sifters for this work are made in a great variety of styles; a plain *vibrating form* is shown in Fig. 21. It consists of a box sieve *a* that is supported on a frame by four flat-steel springs *b* on which the sieve vibrates. The top ends of the springs are bolted to the bottom of the box *a* and the lower ends are bolted to the crosspieces *c* of the frame. The screen receives its reciprocating motion from a cam disk *d* on the driving shaft *e* extending across the top of the frame under one end of the box. The cam acts against a projection *f* attached to the box, pushing the latter horizontally against the pressure of the springs, which return it to its normal position when the cam has passed. The sand is deposited on the screen at the end *a* of the box, the sifted portion passing into the wheelbarrow *g*, and the refuse into another barrow *h* at the lower end of the sieve.

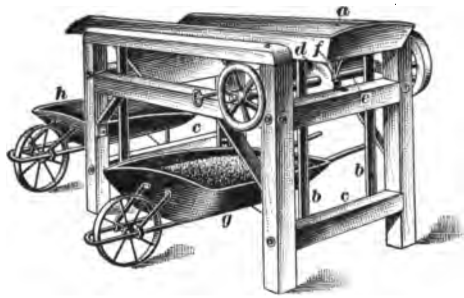


FIG. 21.

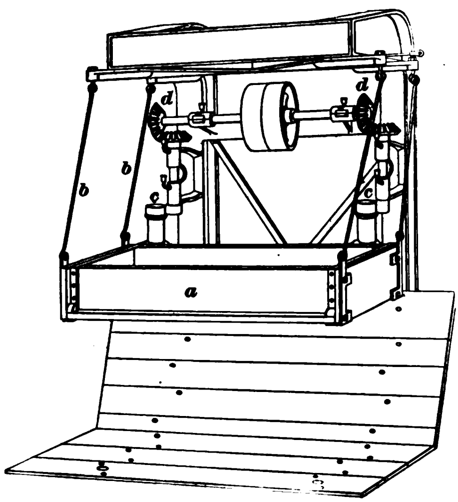


FIG. 22.

Another style of shaking sifter is shown in Fig. 22, which has a box-shaped sieve *a* supported by four rods *b* and to which is imparted a combined oscillating and rocking motion by means of the cranks *c*, *c*. The machine is belt

driven and operates the crank-shafts by means of the bevel gears *d*. This style of machine is also made to operate by hand. The refuse must be removed from the sieve with a shovel whenever necessary. The sifted sand falls on the floor, or into wheelbarrows or a conveyer.

The *pneumatic sifter*, shown in Fig. 23, is portable and is useful for sifting sand as needed at the mold. The ordinary

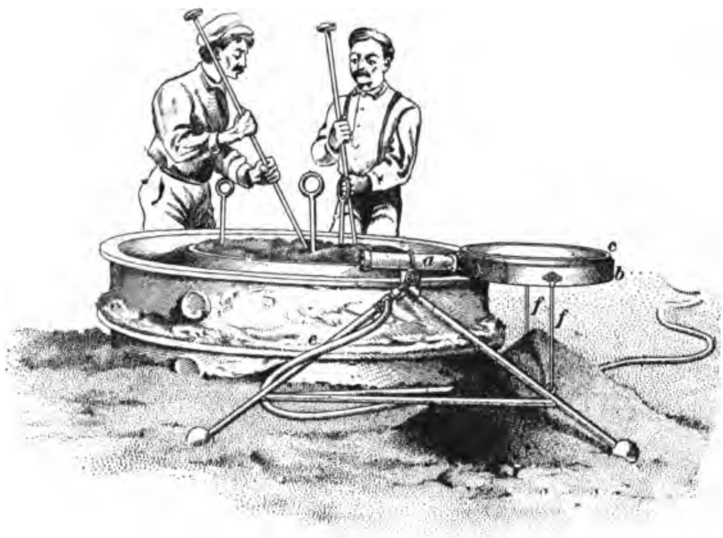


FIG. 23.

form of foundry hand riddle is used in this machine, which consists of an air cylinder *a*, a circular iron frame *b* for holding the riddle *c*, and a supporting tripod. Compressed air is furnished to the cylinder through a hose *e* and gives a rapidly reciprocating motion to the piston attached to the frame *b*. The riddle *c* vibrates on top of the vertical hinged rods *f*, *f*, and the sand that is shoveled into it falls to the floor as it is shaken through the riddle.

A *rotary sifter*, shown in Fig. 24, consists of two hexagonal frames covered with wire screen *a*. A stand *b* supports

the bearings for the shaft *c* of the screens together with either the electric motor *d* or the pulleys, by means of which it is driven; some machines have but one screen. Knockers *e*, *e* are generally used to loosen the sand that clogs the screens. These are pivoted at the ends of arms *f*, *f* attached to the frame of the machine. Lugs *g*, *g* on the ends of the frames carrying the screens, pass under the projections *h* on the ends of the knockers and cause the pads *e* to strike

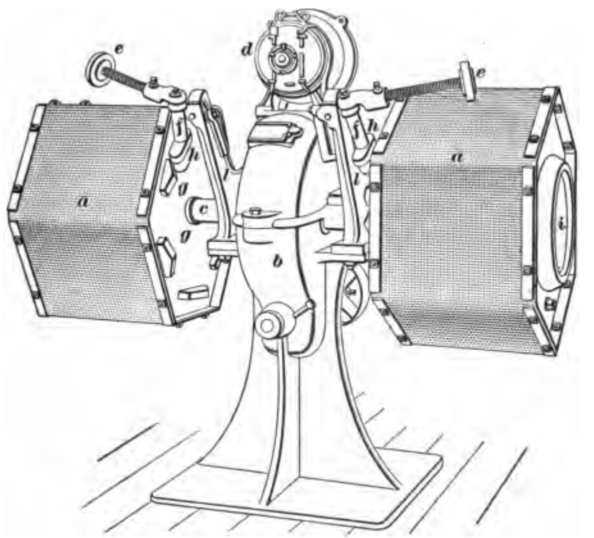


FIG. 24.

the screens. Brushes are sometimes used instead of knockers. The sand enters the hole *i* at the end of the drum either by means of hand shovels or a conveyer. The accumulation of gravel and iron in the drum is removed by opening one section of the screen, although in other designs a conical sieve is used, the sand being fed in at one end and the coarse material passing out at the other end. This style of sifter is sometimes made portable by mounting it on trucks.

23. Magnetic separators are most frequently used to remove the nails and other iron particles from old sand, also in brass foundries to remove iron chips from fine scrap brass or brass chips, where it is very important that all the iron should be removed from the mixture before it is charged into the crucible. They are also used for the recovery of iron from cupola cinder. In brass foundries this mixture is usually made up of scrap and turnings from the machine shop that contain iron and other foreign substances. One form of magnetic separator is shown in Fig. 25. The sand or other material is introduced in a hopper *a* and passes over a revolving brass drum *b*, which has either permanent or electric magnets arranged in the interior in front of the axis of the drum. The iron particles are attracted by the magnets and are carried around to the rear of the drum, where they are removed by a brush *c* or are released by passing out of the magnetic field. The sand or brass passes into the box *d* or into chutes that lead to bins or conveyers while the iron falls under the machine.

FIG. 25.

24. Sand Mixers.—The old-fashioned way, and one that has been universally used, is to mix the sand with the hand shovel. In the larger foundries, mechanical **mixers** are now used. In Fig. 26 is shown one type of mixer, known as the *propeller type*, which consists of an iron

trough *a* for holding the sand and in which a revolving propeller *b* makes a thorough mixture of the old and the new sand, facings, core mixtures, etc. The mixture is dumped

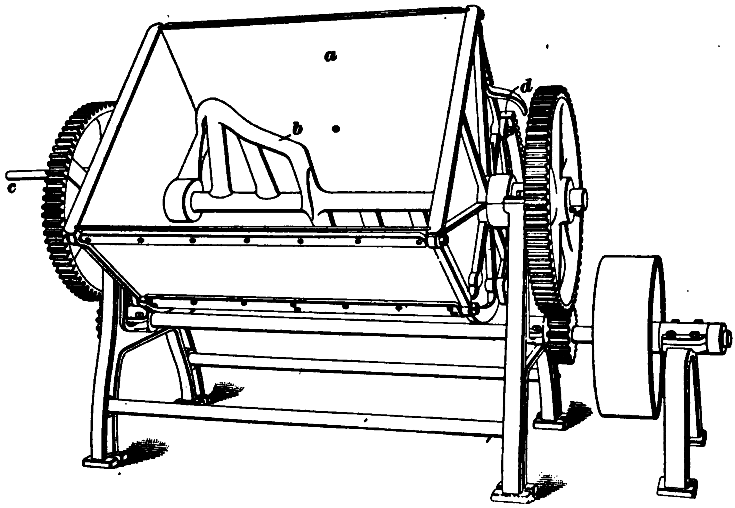


FIG. 26.

out by tilting the trough by means of the crank *c* and a gear that meshes in the rack *d* attached to the trough *a*. Mixers of this type are sometimes equipped with a sand sifter of the form shown in Fig. 21.

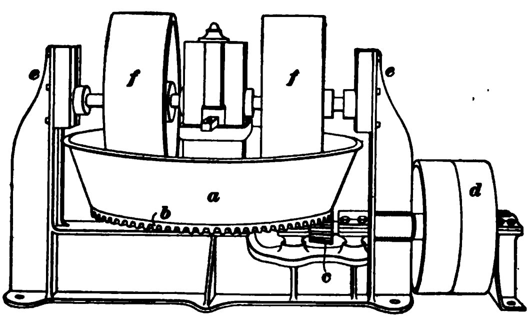


FIG. 27.

Another type of mixer known as the *roller machine*, shown in Fig. 27, is used mostly for mixing loam. It consists of a

large, flat-bottomed, cast-iron bowl *a* that is made to revolve by means of a bevel gear *b* attached to the bottom of the bowl, and a pinion *c* on the shaft carrying the pulleys *d*. The side supports *e* carry bearings for a shaft, on which are placed two heavy broad-faced rolls *f*, *f*. The loam is put into the bowl by means of shovels, or a conveyer, and as the bowl revolves, the rolls pass over the loam and pulverize it.

A *centrifugal mixer* that depends for its operation on the centrifugal force of the sand is shown in Fig. 28 (*a*) and

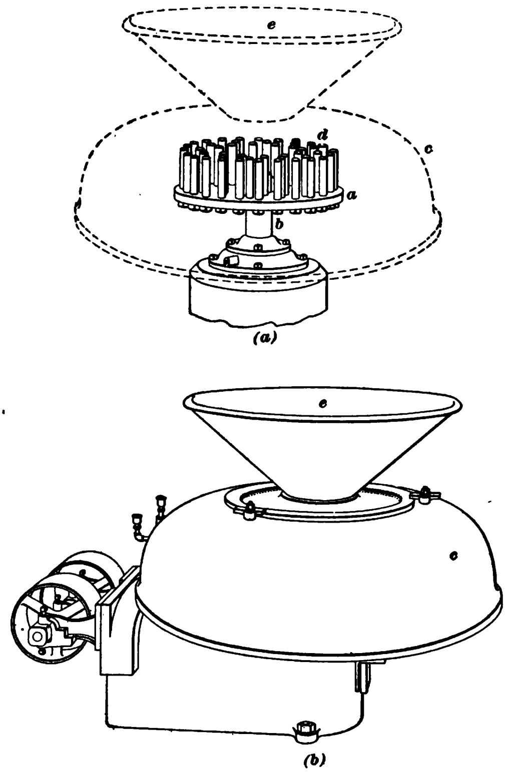


FIG. 28.

(*b*). It consists of a disk *a* mounted so as to be rapidly revolved on the top of a vertical shaft *b* and enclosed in a

cast-iron case *c*. On the upper surface of the disk a series of steel pins *d* are fixed. The sand is introduced through a hopper *e* at the top to the center of the rapidly revolving disk and is thrown outwards through the pins. In passing between the pins the lumps are pulverized and the material thoroughly mixed. The mixture falls from the bottom of the case *c* either on the floor or into the trough of an underground conveyer and is ready for immediate use with the possible exception of tempering.

25. Sand Temperers. — The water for tempering sand is usually supplied from a hose or sprinkling can, and the sand tempered by hand. A mixing machine, shown in Fig. 29, having a heavy boiler-iron tank similar to the mixer

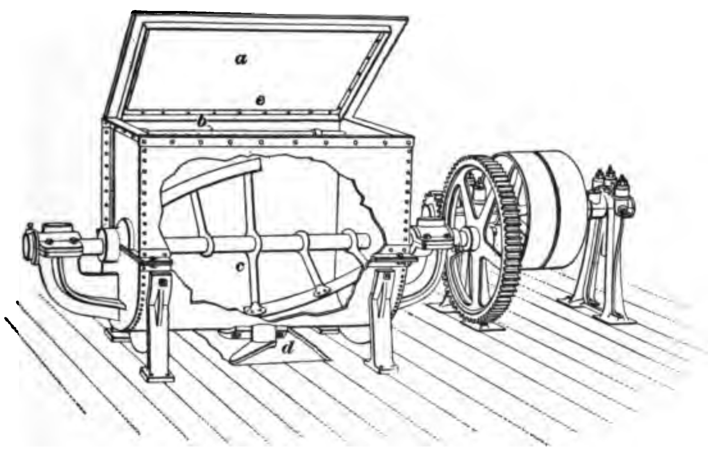


FIG. 29.

shown in Fig. 26, but with a cover *a*, is frequently used for this purpose. A spray of water is thrown on the sand through a perforated pipe *b* while it is being mixed by the revolving propeller *c*. A door *d* in the bottom of the box is arranged so that the sand may be withdrawn, when it is mixed and tempered, either directly into a wheelbarrow or into the hopper of an underground conveyer.

26. Sand Elevators.—After the molding sand has been prepared for use, it must be delivered to the various places where it is used. This may be done in wheelbarrows or trucks, or by means of a system of conveyers that is placed overhead; if a conveyer system is used, an elevator is necessary to raise the sand to the level of the conveyer. An underground conveyer delivers it to the base or boot of the elevator. One of the simplest and most efficient elevators, shown in Fig. 30, consists of a belt *a* (leather, rubber, or steel), carrying buckets *b*, which passes over a drum *c* at the top and under a similar one at the bottom. Chains are sometimes used for this purpose, but leather, rubber, or steel bands are better able to withstand the abrasive action of the sand. The working parts are generally enclosed in a wood or iron case *d*. The buckets of the elevator deliver the sand to the trough of the overhead conveyer. The power is applied to a pulley or gear on the shaft of the upper drum. About 40 feet per minute is the best speed for a sand-elevator belt. Vertically movable bearings, which may be adjusted by means of the screws *e*, are provided in the top carriage for the purpose of taking up the slack in the belt. The pocket *f* about the foot of the

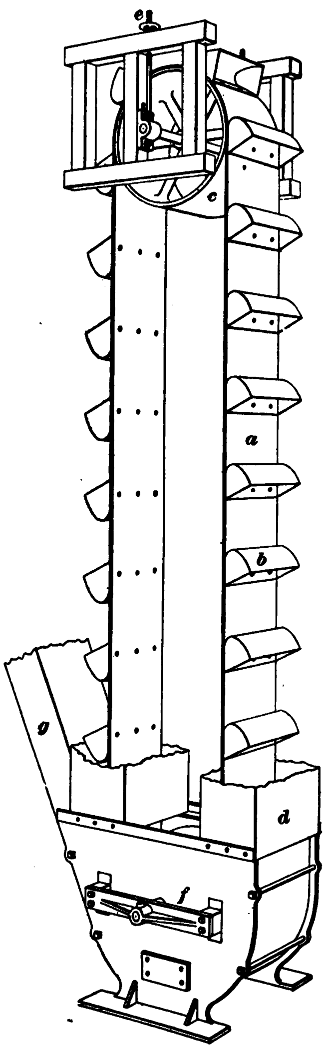


FIG. 30.

elevator is called the **boot,** and the material to be raised is introduced into it through a chute *g*.

27. A **mold conveyer** is an appliance used in some of the large foundries to transfer the molds, cores, etc. from the benches and molding machines to the cupola or the casting room, and to return the empty flasks to the molders. With such a device it is possible to divide the foundry into two departments—the molding room and the casting room. This system applies to small and medium-sized work, which can be made in portable molds. For large work the molten iron is carried to the molds, necessitating the use of a

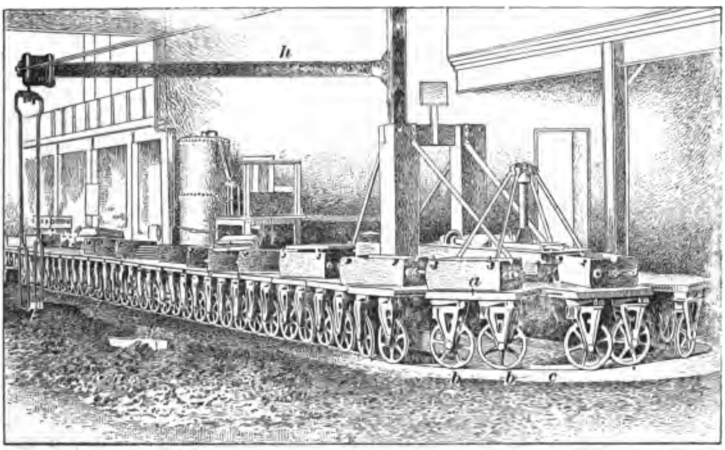


FIG. 31.

traveling crane, jib crane, trolley, or truck ladle. In the smaller foundries, and in many larger ones as well, the molds are arranged on the floor near the cupola and the molten iron carried to them. Figs. 31 and 32 show one style of mold conveyer, which consists of a train of trucks *a* with iron tops connected close together to an endless link belt so as to form a continuous traveling platform. The belt travels around a large sprocket sheave at each end of the line. The outer edge of each truck is supported by two wheels *b*, *b* that are grooved to fit a rail *c* laid level with

the floor and extending along the entire conveyer circuit through the molding department and around the cupolas

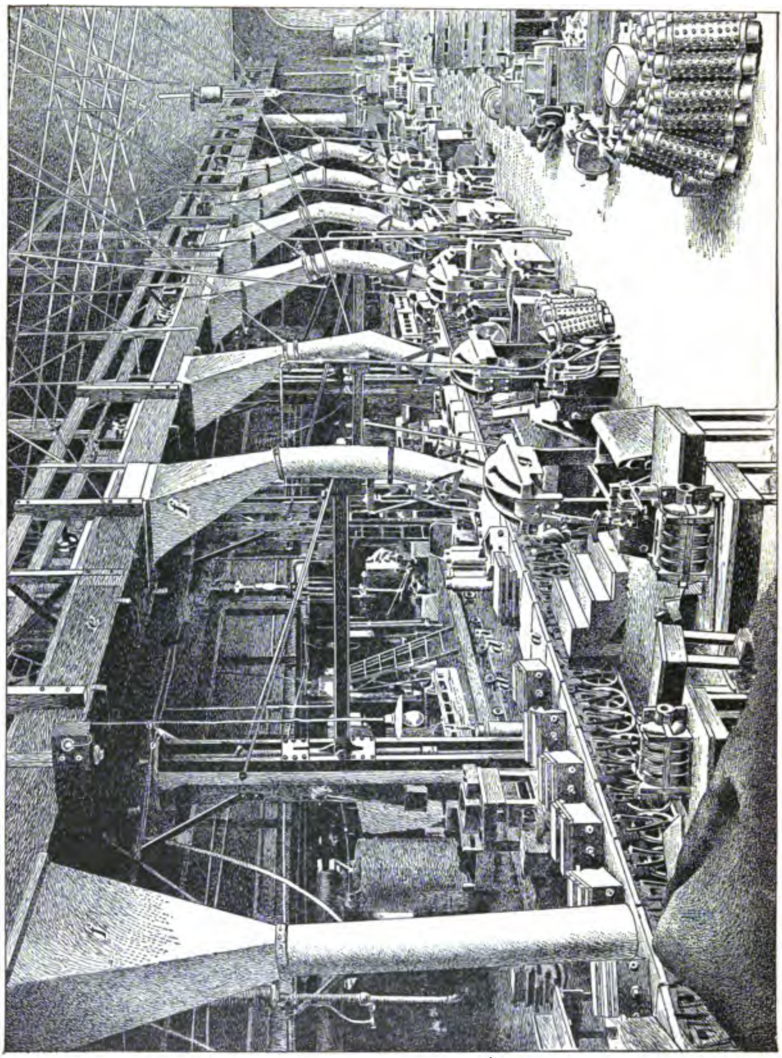


Fig. 32.

and casting platform. The inner edge of the top of each car is supported by grooved wheels *d* running on a **T** rail *i*

near the top of the cars. Where such a system is used, the cupolas are located on a base raised a few feet above the floor level, and at the same height as the top of the conveyer, so that the men pouring the molds may easily step from the floor to the top of the conveyer. The molders are located along the conveyer in the molding room.

Molds made in the machines *g* and on the floors are preferably deposited on the conveyer in halves. The drags are supplied with cores, and the flasks closed by the core setters. Large molds, especially those requiring large or heavy cores, are brought to the casting floor, removed from the conveyer, and bedded on the floor; the cores that follow them on the conveyer are then set. Bench molders and those using snap flasks usually set their own cores, close the molds, and place them on the conveyer. The molders have completed their part of the work when they have deposited either the finished or open molds in good condition on the conveyer. Jib cranes *h* or trolleys with air hoists are sometimes used to lift the molds on and off the conveyer. The finished mold is poured while on the conveyer as soon as it comes within convenient reach of the casting gang, who draw the metal in shank ladles from the cupolas, step on the conveyer, and pour the iron while in motion. In some cases the ladles are carried by means of a trolley running on a track that runs over and parallel to the conveyer. The molds are taken from the conveyer when near the cleaning room, shaken out over a grating, which allows the sand to fall into an underground sand conveyer, and the empty flasks are returned on the conveyer to the molder. The cores are removed from the sand and the gates knocked off the castings, which are taken to the cleaning room. For large work, the motion of the conveyer is controlled by an operator, who starts it forwards whenever a section is loaded with molds. This intermittent movement allows all the molding operations to be carried on simultaneously. Conveyers of this type for small work run continuously, the molds being put on while it is in motion. Sand for the molding machines *g*, Fig. 32, is

brought by a conveyer *e* to the hoppers *f*, the conveyer *e* being like the one illustrated in Fig. 19.

28. Another form of conveyer, shown in Fig. 33, consists of two endless steel bands *a*, *a* passing over large pulleys at the terminals and supported throughout their length on a steel framework *b* that carries rollers *c* at short intervals at about the floor level. The upper bands carry the

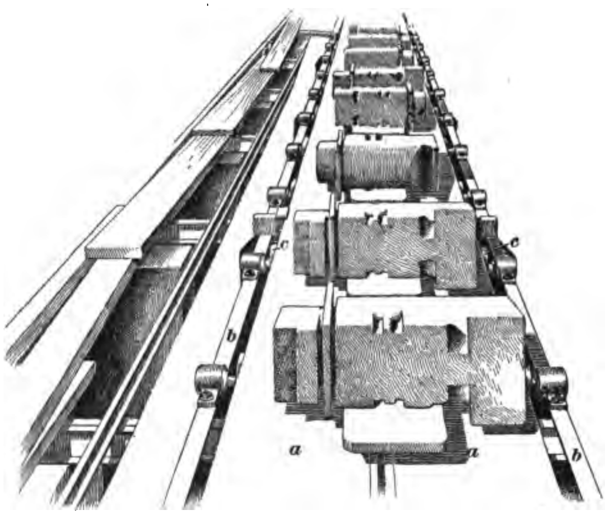


FIG. 33.

molds to the casting room, where they are removed to the floor and the flasks completed for pouring. After shaking out, the empty flasks are returned on the lower bands of the conveyer, which run in a pit under the upper bands *a*, to the molding department. The illustration shows the conveyer loaded with cores for railway-car journal-boxes. Conveyers of this type are preferably located centrally in the building, with the molding machines arranged in line along both sides. By leaving a passageway from the conveyer to the rear of the machines, the floor and bench molders are enabled to deposit their finished work on the conveyer and receive cores and empty flasks from it. In some cases it is desirable to arrange the machines and the benches at right

angles to the conveyer, or in various other ways to best suit the existing conditions.

29. Charging-Floor Elevators.—The elevators used to deliver the iron, coke, and other materials from the ground

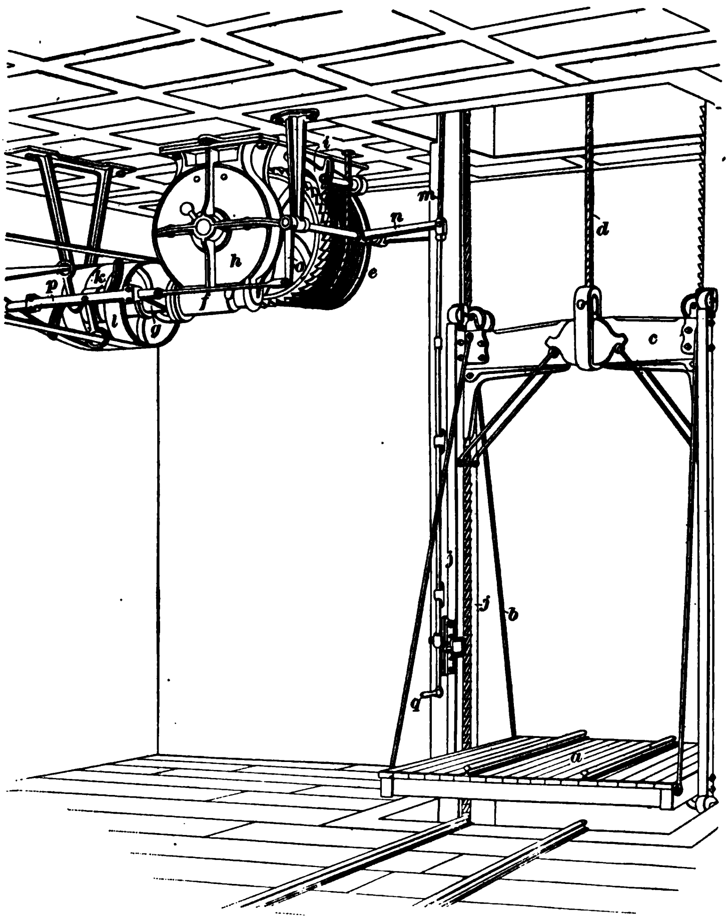


FIG. 34.

to the cupola charging platform are operated either by belts, hydraulic cylinders, compressed air, or electric motors. Their speed is from 60 to 80 feet per minute. The platform

should be large enough to accommodate one or more cars used for hauling the materials. It is an advantage in some cases to use double elevators. A single elevator must be balanced by counter weights, while double elevators balance each other and give double service with only a little more power than is required by the single one. The old style of

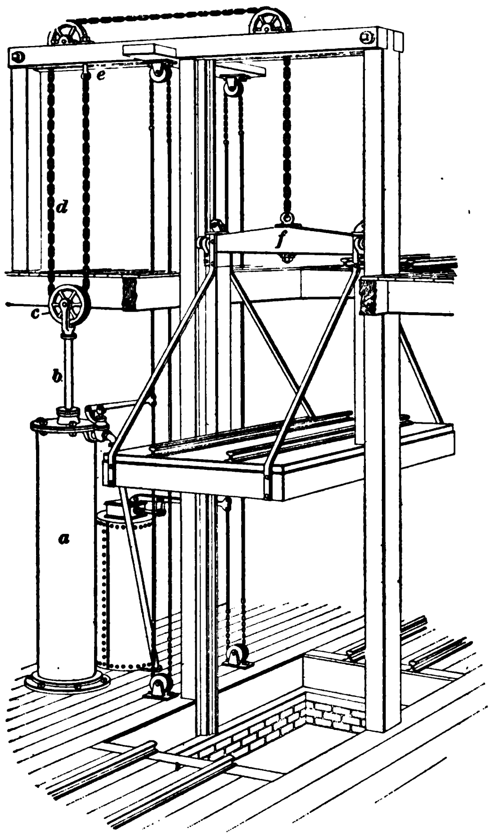


FIG. 35.

drum hoist, shown in Fig. 34, is extensively used. The cage consists of an open platform *a*, uprights *j*, braces *b*, and a cross-tree *c*, to which the cable *d* is attached. The cage works between guides on each side. The cable *d* passes over a large sheave at the top of the tower and returns to

the winding drum *e*, which is fastened by suitable bearings and base frame to the overhead joists. A worm in the case *f* on the shaft supporting the pulley *g*, drives the worm-gear in the case *h*, which is rigidly attached to the drum shaft. The safety catch *i* holds the drum and the load in any desired position when the driving power is shut off.

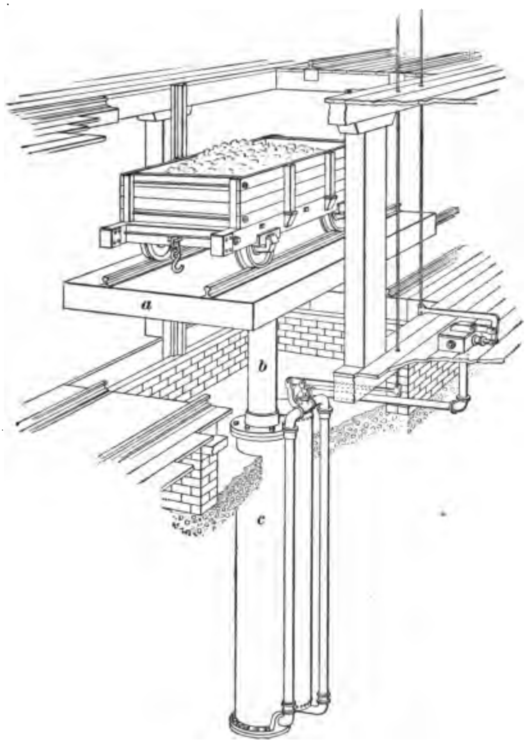


FIG. 36.

The belt runs continuously, and to start the elevator it is necessary to shift the belt from the loose pulley *k* to the tight pulley *l*. This is done from above by pulling the rope *m*, attached to the shifting mechanism *n*, *o*, and *p*, or from below by the handle *q*. Electric motors are often used to operate this style of elevator, the motor being connected directly to the screw gear.

The same general form of cage is also operated by a hydraulic cylinder *a*, as shown in Fig. 35. The piston rod *b* carries a pulley *c* that engages a loop of the chain or cable *d* passing from the eyebolt *e* to the cross-tree *f* of the cage. With a single sheave on the piston rod, the lift and speed of the cage is double that of the piston. Any desired ratio of speeds can be secured by using sheaves at *c* and *e* with a suitable number of grooves. This form of elevator is generally used for high-speed work.

Hydraulic elevators are also so arranged that the platform *a*, as shown in Fig. 36, is placed directly on the end of a plunger *b*, which works in a hydraulic cylinder *c*. The load is lifted by forcing water into the cylinder under the plunger, and is lowered by its own weight when water is discharged. This style of elevator is used for heavy service. Its speed depends on the rate the water fills or empties the cylinder *c*.

30. Pig Breakers.—When full-sized pigs are used in making up the cupola charges, there is danger of injuring the lining, disturbing the coke bed, and making unsatisfactory open piling; they are also inconvenient to handle. Hence it is common practice to break them into two or more pieces. This is usually done by hand with a heavy sledge. Some founders, however, employ hydraulic or belt-driven **pig breakers** that give good service. Sandless pig is often small and requires no breaking.

31. Economical Production.—The purpose of the use of labor-saving appliances in a foundry is to produce castings at a lower cost. But to secure the greatest benefits from such appliances, there must be not only a careful selection of each, both in kind and number, but also a systematic arrangement of the whole plant so that each appliance may operate to its fullest capacity on the particular line of work for which it is designed. In the larger foundries the greatest subdivision of the various operations is most necessary. The economical manufacture of castings is best accomplished by using all the appliances in unison

and assigning to each employe distinct and limited operations to perform; that is, a molder should do molding exclusively, one set of men should set cores, another close flasks, and other men should shake out and remove castings, a carpenter should repair flasks, and so on with all the foundry operations. The flasks, sand, cores, and all materials should be brought to the molder. The molten iron may be brought to the flasks or the flasks taken within easy reach of the casting gang. No employe should have cause for leaving the immediate work in hand, or for using the tools of another, and the arrangement should be such that each man is required to do his share. The employes should have short hours and good wages and be required to perform the least amount of unnecessary labor, but, on the other hand, they should be required to turn out the greatest possible amount of good work during the working hours. The molder should make the best use of his manual skill and intelligence in performing the work assigned to him, and the foreman and superintendent should carefully plan and direct the work.

FOUNDRY APPLIANCES.

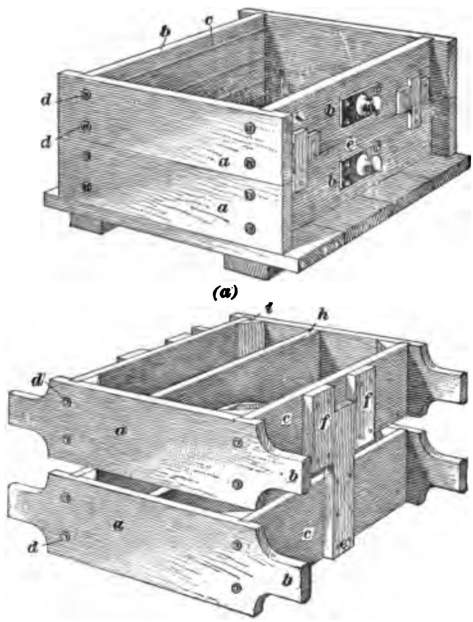
(PART 2.)

SMALL MACHINES AND APPARATUS.

FLASKS, CORE ROOMS, AND CLEANING OUTFITS.

FLASKS.

1. Flasks are the most important appliances used in molding operations. They vary in size according to the class of work to be made, and should be selected so that the use of the smallest quantity of molding sand will produce good castings, but at the same time large enough to prevent the loss of castings on account of an insufficient body of sand to hold the metal in place. Flasks should be made as light in weight as possible without impairing their strength and stiffness, so as to be easily and cheaply handled. Nearly all foundries confine their operations to the production of castings of one class, or at most to only a few classes. Jobbing foundries are at a disadvantage in this respect, as they are compelled to keep a large assortment of flasks. Specialty foundries have the best opportunity to cut down the variety of flasks to a minimum.



(a)

(b)

FIG. 1.

2. Large Wooden Flasks.—Fig. 1 (*a*) shows a flask for heavy work. It is made of thick lumber, the side pieces *a* being grooved to receive the ends of the end pieces *b*, and the parts are held securely together by means of bolts *c* with nuts and washers *d*. Trunnions *e* are provided at the ends of heavy flasks so that they may be raised or turned by means of hoists. In Fig. 1 (*b*) is shown a wooden flask designed for work of medium weight. The sides *a* have extensions *b*, *b*, which serve as handles by means of which the flasks may be lifted and turned over by hand. The sides are fastened to the ends *c* by means of lagscrews *d* and washers. A strip of wood *e*, fastened to the drag, slides between the strips *f*, *f*, fastened to the cope, which serve to keep the two parts of the flask square with each other. Heavy wooden flasks may also be strengthened by corner blocks *i*. Wooden flasks are made of pine, white wood, hemlock, or chestnut lumber.

3. Large Iron Flasks.—In steel foundries where the molds are submitted before pouring to a drying process in an oven, the flasks must be made of iron, as shown in Fig. 2. The ends and sides of this flask consist of metal plates *a* of medium thickness reenforced by ribs *b* on the outside. The

bottom board *c* is held to the flask by means of **U**-shaped clamps *d* and wedges. Either cast iron, wrought iron, or steel is used in the construction of this style of flasks, and the sides and ends are either bolted or riveted together. Steel flasks for large work are sometimes made so that they can readily be increased or decreased in size so as to accommodate work of different sizes. This is done by making both the sides and ends of the flasks of two pieces that overlap and are provided with a series of holes so that they may be bolted together to make up different sizes.

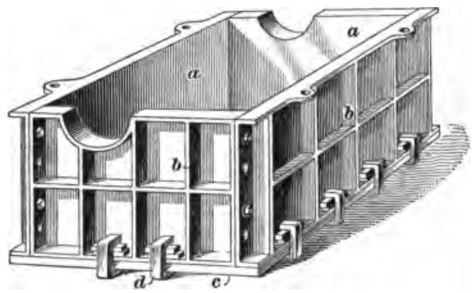


FIG. 2.

4. While large castings are usually molded in loam, the disadvantages of this method as compared with dry-sand molding in flasks are thought by some founders to outweigh the advantages, and they have adopted the latter method. The first cost of making a large iron flask with all the necessary appliances for dry-sand molding is much greater than that for the preparation, materials, and appliances for molding the casting in loam, but when a number of the castings is required, the lower first cost of the loam-molding equipment is offset by the lower cost of the dry-sand mold when once the necessary appliances are provided, and hence if a large number of heavy castings from a given pattern is required, it is generally cheaper to use dry-sand molds. The cleanliness of the molding floor and the economy of time and floor space are also in favor of the molding in flasks. The relative prices of sweeps and patterns used in both methods will depend on the form of the casting.

In Fig. 3 is shown an iron flask for molding the 43-ton engine bedplate, shown in Fig. 4; the side and end elevations

of the flask and the method of fastening the cross-bars are shown in Fig. 5 (*a*), (*b*), and (*c*), and the longitudinal and transverse sections and plan of the mold in Fig. 5 (*d*), (*e*), and (*f*). The bedplate is molded upside down, as shown by

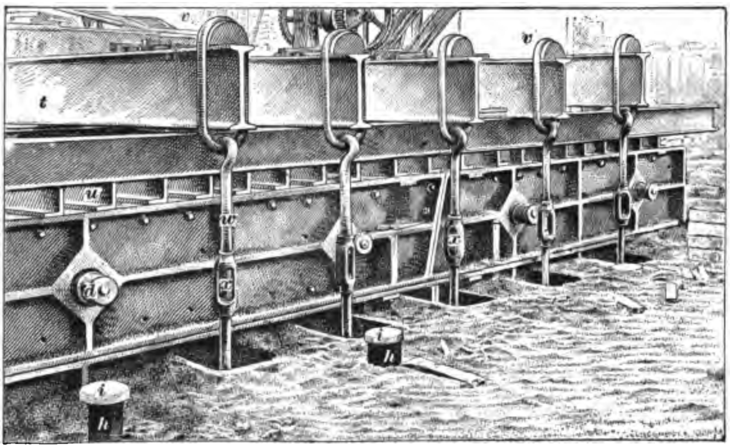


FIG. 3.

the pattern *a*, Fig. 5 (*d*) and (*e*), because the smoothest and best side of a casting is that at the bottom of the mold, and in this case all the machined surfaces are on the top of the bedplate. The sides and ends of the flask are cast-iron plates reenforced by heavy ribs *b*, and fastened together by means of bolts running through the flanges *c* along the edges and across the ends, as shown in Fig. 3 and Fig. 5 (*a*), (*b*), (*c*), (*d*), (*e*), and (*f*). It is very important that in the construction of large flasks, which are lifted by means of trunnions *d*, Fig. 3, that the plates be made very stiff, and that the corners be flanged and bolted so that they will not be distorted when the flask is lifted. Any distortion of the corners or plates will cause the sand to spread and injure the mold.

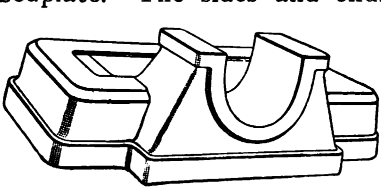


FIG. 4.

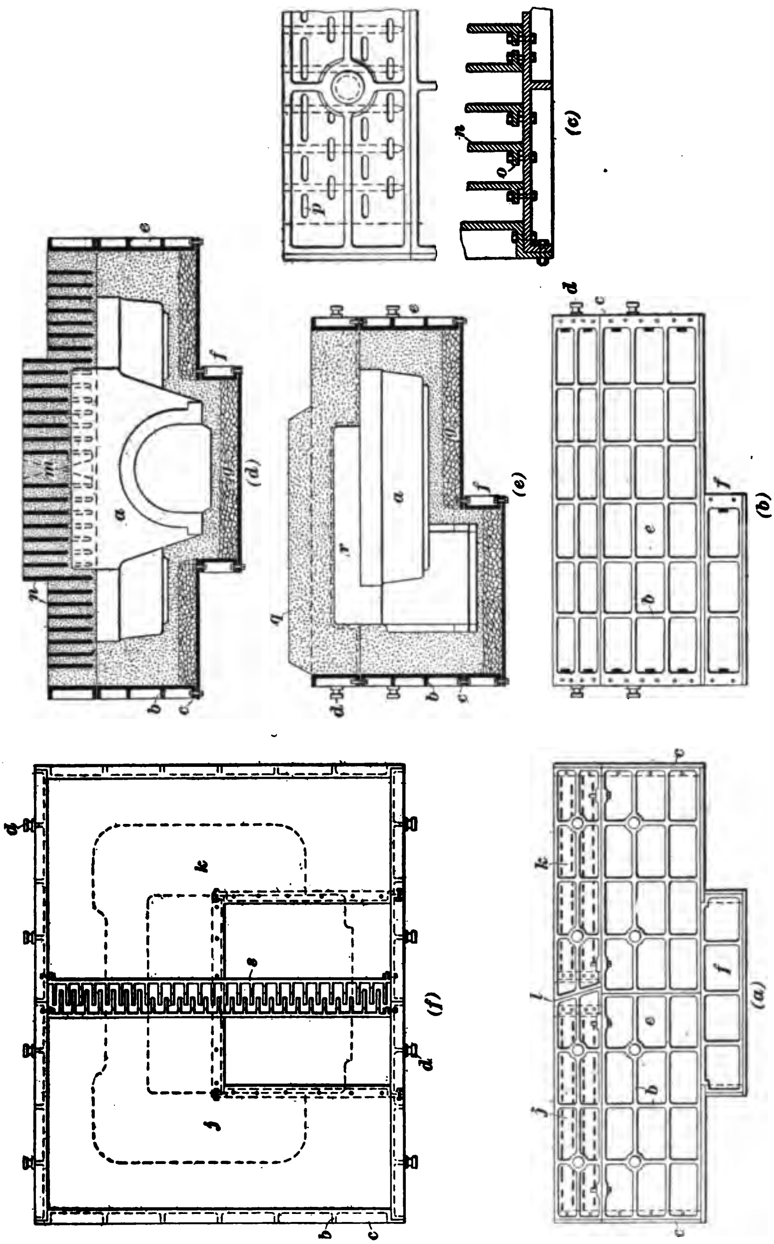


FIG. 5.

The drag *e*, Fig. 5 (*a*), has an extension *f* on the bottom and is placed in a pit about 7 feet deep. The foundation for the drag consists of 18 steel **I** beams resting on two cast-iron bearing bars 6 inches square, which extend lengthwise at the sides of the flask. The bottom of the flask is made of $\frac{1}{2}$-inch steel plates laid on the **I** beams. A bed of coke *g*, Fig. 5 (*d*) and (*e*), about 10 inches deep, is spread on the bottom and vented by a number of 4-inch wrought-iron pipes extending through the sides of the drag and brought to the surface of the foundry floor by the risers *h*, shown in Fig. 3; the caps *i* on top of the risers are used to prevent sand from entering the pipes, and are removed when the mold is being poured.

The lower portion *f* of the drag is 8 ft. 11 in. × 9 ft. 5 in. × $22\frac{1}{4}$ in., and the larger part *e* is 17 ft. 4 in. × 21 ft. $1\frac{3}{4}$ in. × 4 ft. 8 in. The cope is in two pieces *j* and *k*, Fig. 5 (*a*), united by a diagonal joint *l*. A tapered dry-sand core *m*, Fig. 5 (*d*), is used to close the mold after the two parts of the cope are in place, the opening serving for an entrance for a molder to inspect the mold before it is finally bolted together. The core arbor for holding the core *m* is shown at *s*, Fig. 5 (*f*).

The cross-bars *n*, Fig. 5 (*c*) and (*d*), are of cast iron and are fastened to the sides of the cope by means of bolts through flanges *o* at each end of the bars and slots *p* in the cope, the slots permitting lateral adjustment of the bars. The cross-bars are elevated in a portion of the cope, as shown at *q*, to allow room for the extension of the core *r*. The estimated weight of this cope when rammed with sand is 60 tons, but it is necessary to bind the parts of the flask securely together to prevent the molten metal from lifting the cope. A series of steel **I** beams *t*, Fig. 3, are placed across the top of the flask. The lower ones run lengthwise of the cope, and are supported on a row of angle bars *u*, which elevate the **I** beams above the projection *q*, Fig. 5 (*e*), of the mold. The ends of the top beams extend over the sides of the mold and are fastened to the two 6″ × 6″ cast-iron bars in the foundation by means of heavy iron loops *v*

and rods w, Fig. 3, the tension being regulated by means of turnbuckles x in the rods.

5. Flask Pins.—In order to hold the two parts of a flask together and to have them accurately match each other, it is necessary to fit one part with two or more pins and the other with sockets to correspond with the pins. Flask pins are made of round, square, triangular, or diamond-shaped cross-sections. Any of these forms is satisfactory provided the pin is well made and carefully fitted. They are

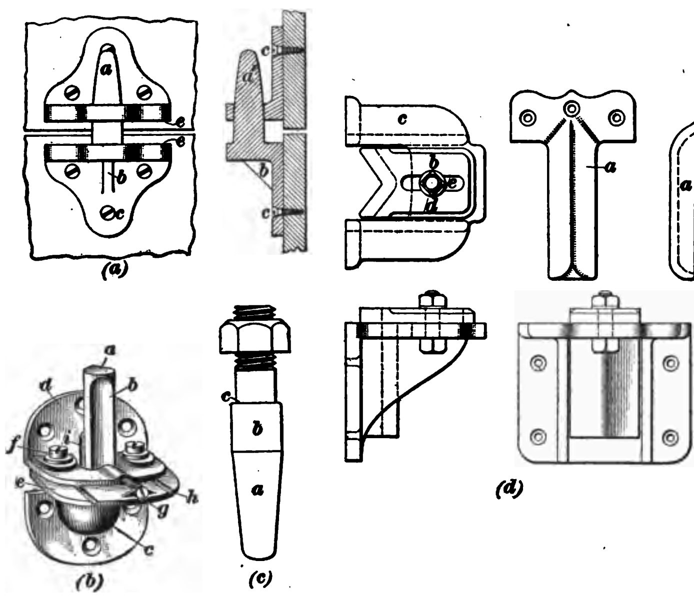


FIG. 6.

made of cast iron, malleable iron, brass, or steel, and in some cases deep wooden flasks have strips of wood of the form shown at e and f, Fig. 1 (b), in place of pins. Strips of this form are sometimes placed on deep flasks in addition to the regular style of pins. Fig. 6 (a) shows a solid pin, (b) an adjustable one, and (c) a steel pin. The flask pin shown at a and in vertical section at a', Fig. 6 (a), is cast solid with the lug b and the plate that is fastened to the

drag by means of the screws *c*. The pin is tapered so as to easily enter the hole in the lug *d* on the cope. The adjoining faces *e*, *e* of the lugs should not meet when the flask is closed, but should be from $\frac{1}{8}$ to $\frac{1}{4}$ inch apart; otherwise, the sand that accumulates on the lower lug while molding will prevent a close fit between the cope and drag.

Small iron flasks, especially those used on molding machines, require pins that fit very accurately. One form of pin suitable for this style of flask is shown in Fig. 6 (*c*). These pins are made of steel; they are from 3 to 4 inches in length over all, and all the parts are machined. The pin has a tapered portion *a* at one end to facilitate its entrance into the hole in the lug on the cope, and a cylindrical part *b* that accurately fits the hole. The pin is fastened into a hole in the lug on the drag by means of a nut on the threaded end of the pin that clamps the lug against a shoulder *c* on the pin.

6. Rectangular iron flasks usually have four pins, one near each corner, and round flasks, three pins. Where flasks are not interchangeable, the pins are frequently made adjustable, so that when the flasks become sprung or bent out of shape from use the pins can be made to fit accurately. As a rule, only small flasks can be made interchangeable on account of the fact that the different parts of large flasks become sprung so that the pins will not fit. Fig. 6 (*b*) shows an adjustable pin that has the socket on the cope made in two parts *d* and *e* that are fastened together by means of two screws *f*. The movable plate *e* is adjusted under the upper plate by means of a screw *g*, so as to make a snug fit between the pin *a* on the piece *c* and a vertical **V**-shaped projection *i* on the edge of the movable plate *e*. The plate *e* is guided by two grooves *h* that fit corresponding projections in the stationary part *d*.

An adjustable pin for flasks for floor molding is shown in Fig. 6 (*d*). The pin *a* is fastened to the drag by means of three screws. The socket on the cope is made in two pieces *b* and *c* fastened together by means of a $\frac{3}{8}$-inch bolt *d*, through

a slot *e* in the movable part *b*, and permits the latter to be adjusted so that when the cope and drag are put together, the pins *a* fit into the V-shaped groove in the edge of the adjustable part *b* of the socket, freely, yet without any unnecessary lost motion.

7. Cross-Bars.—Cross-bars are frequently introduced into the cope portion of a flask to support the sand. The cross-bars *h*, shown in Fig. 1 (*b*) and at *a*, Fig. 7 (*a*) and (*b*), are preferably made removable to facilitate the adaptation of the same flask to different patterns. The wooden cross-bars are generally made tapering toward the bottom *g*, Fig. 7 (*b*), and a part of each bar is usually cut away from the lower side, as shown at *j*, Fig. 7 (*a*), so as to conform to the shape of the patterns to be molded. It is an advantage to make cross-bars of cast iron if they are to be used for standard work, as they are inexpensive, strong, and serviceable. If made of cast iron, they are preferably provided at each end with a flange *b*, Fig. 7 (*a*), by means of which they are bolted to the sides *c* of the flask, and should be provided with either holes or projecting pins to assist in supporting the molding sand. In order that gaggers *d*, *d*, Fig. 7 (*a*) and (*b*), may be used safely and conveniently, the top edge of the cross-bars should stand about 1 inch or more below the top edge of the flask, so that when one end is hung over the cross-bars it will not project beyond the top surface of the mold.

8. When long cast-iron cross-bars are used, they must be supported by cross-braces to prevent them springing sidewise out of a straight line when the sand in the flask is being rammed. Cast-iron cross-bars are also put closer together than wooden ones. In Fig. 7 (*c*) and (*d*) are shown two methods of bracing cast-iron cross-bars. The cheaper and easier method is to drive wooden blocks *i* between the cross-bars *h*, as shown in Fig. 7 (*c*), using one or more rows of blocks, depending on the length of the cross-bars *h*. The blocks are placed between the bars, as shown at *k*, Fig. 7 (*c*), and then driven so as to stand square, as shown at *i*. The

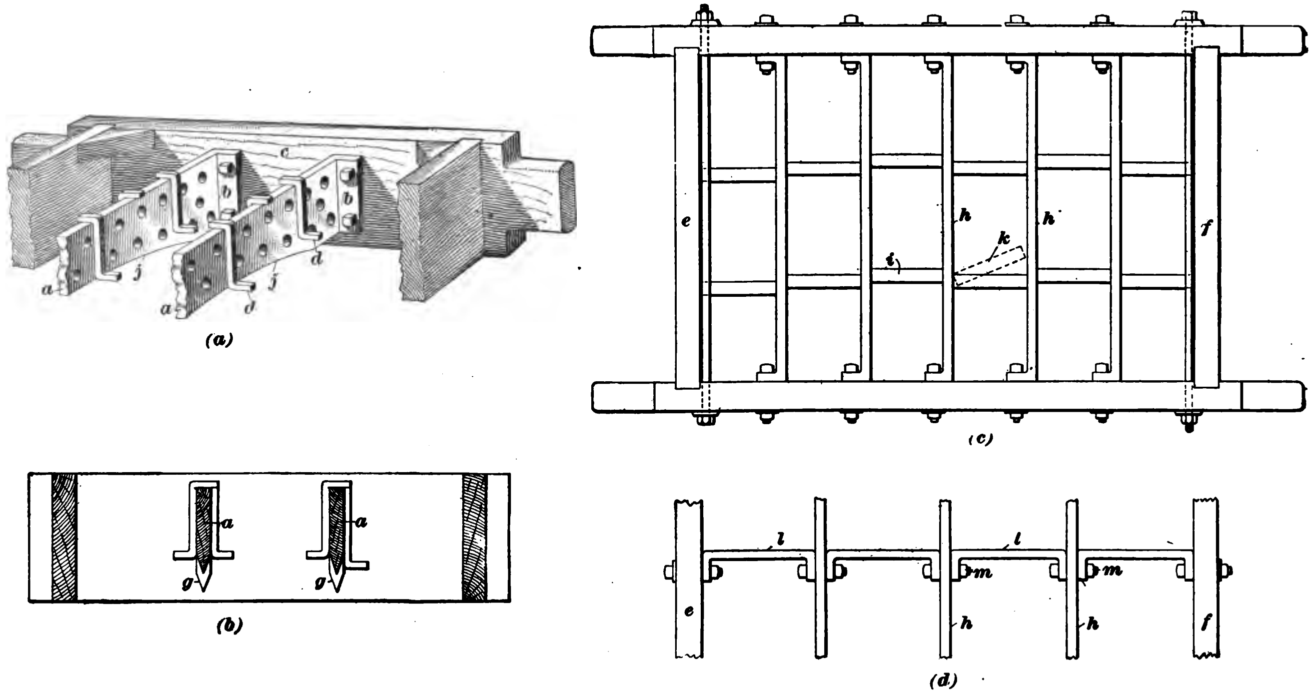


FIG. 7.

tendency of the wood braces is to bulge the ends of the flask. The ramming of the sand also bulges the ends of the flask and tends to loosen the braces. The better method to brace the cross-bars is to use cast-iron pieces *l*, which are bolted to the cross-bars *h* and to the ends of the flask *e* and *f*, as shown in Fig. 7 (*d*); these iron pieces act both as braces and ties. The bolts *m* pass through holes in the flanges of the braces and slots in the cross-bars, the slots permitting a lateral adjustment of the braces.

9. Small Iron Flasks.—Jobbing foundries, almost without exception, use wooden flasks exclusively, while specialty and brass foundries generally use iron flasks. Iron

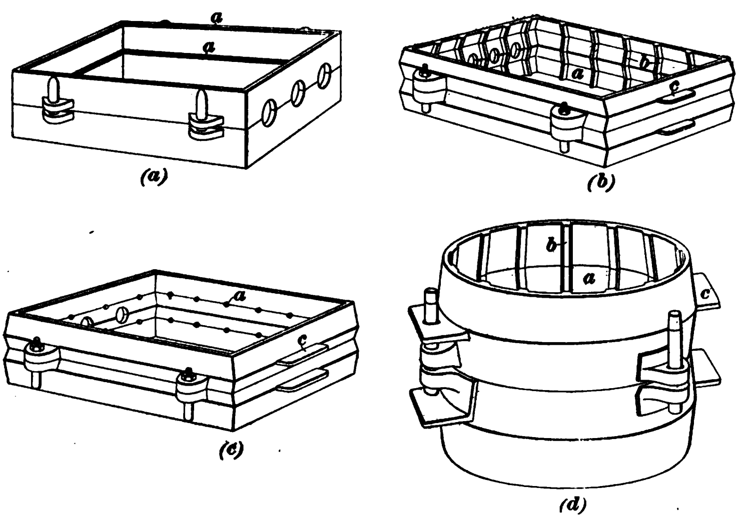


FIG. 8.

flasks give better satisfaction than wooden ones; they have a longer life, are stiffer, do not burn, and are safe and convenient to handle. They are specially designed to obtain strength and light weight; standard sizes are from 12 to 60 inches in length and from 4 to 16 inches in total depth. For the purpose of holding the sand in the flasks, the interior edges are provided with horizontal ribs at the top, bottom, and parting lines, as shown at *a*, Fig. 8 (*a*), and sometimes,

in addition to these with double-beveled ribs *a* and perpendicular ribs *b*, Fig. 8 (*b*) and (*d*), or with another form known as a *porcupine spine*, shown at *a*, Fig. 8 (*c*). Fig. 8 (*d*) illustrates a circular iron flask with double-beveled ribs *a* and vertical ribs *b*. The round flasks have three pins and the others four, two on each side. Many of the best iron flasks are fitted with steel pins. Flasks used on molding machines should always be made of iron and have good fitting and interchangeable pins, so that the cope of one flask can be used with the drag of another flask of the same dimensions. Iron flasks generally have lugs *c*, shown in Fig. 8 (*b*), (*c*), and (*d*), for handles.

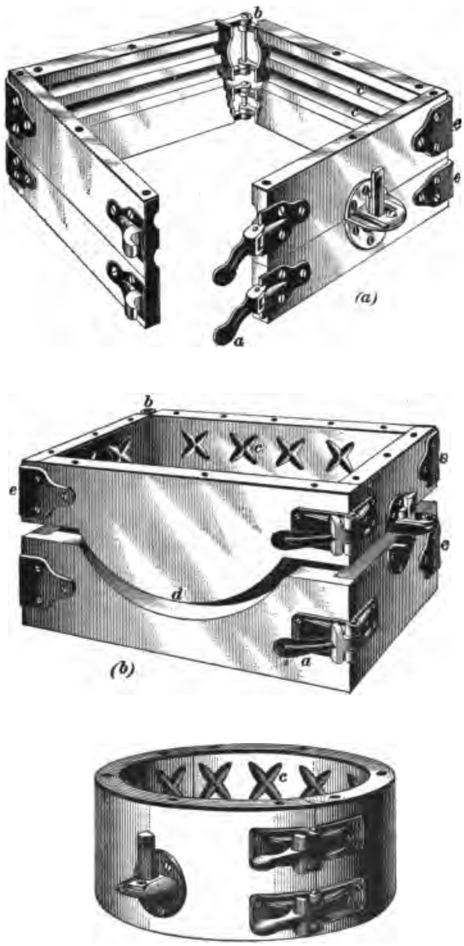

(c)

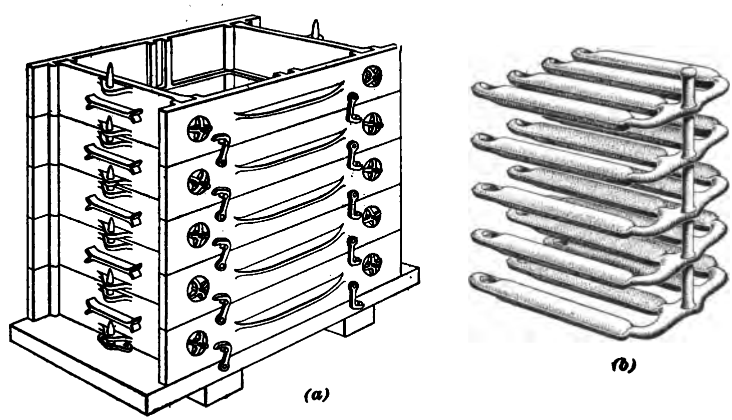
Fig. 9.

10. Snap Flasks. It is often desirable in molding small castings to have flasks that can be removed from the molds. Flasks for this purpose are called **snap flasks,** and are constructed as shown in Fig. 9 (*a*), (*b*), and (*c*), with clasps at *a* and hinges at *b*, so they can be opened and removed

from the mold. The inside faces are usually grooved as shown at *c*, to assist in molding the sand while removing the flasks. The flasks are sometimes made with a taper, being larger at the bottom than at the top, so as to facilitate the application of slip boxes over the molds after the flasks have been removed. Snap flasks are made of white wood, or selected cherry, well saturated with boiled linseed oil, and are rectangular, square, or round, as shown in Fig. 7 (*a*), (*b*), and (*c*). The parting line is sometimes of special form, as shown at *d*, Fig. 9 (*b*), to conform to that of the patterns. The flasks should be light and strong with the corners iron-bound, as shown at *e*, *e*, Fig. 9 (*a*) and (*b*). The clasps are made of malleable iron, and should be quick acting and good fitting.

Standard sizes of snap flasks vary from 9 to 12 inches in width by 10 to 20 inches in length, and the copes and drags vary from 2 to 6 inches in depth.

11. Nests of Flasks.—Iron flasks if constructed so as to be fastened together by means of hooks and pins, as shown



(*a*) (*b*)

FIG. 10.

in Fig. 10 (*a*), are used in nests for multiple molding. With this style of flask each section forms the cope for one mold

and the drag for the section immediately above it. The molds are made in machines that form a half mold on each side. By placing them on top of one another, they form a complete mold between each pair of sections. Each section has a sprue, except the bottom one. This method of molding saves time, sand, and space, and it can be applied to the rougher class of work for articles of simple designs and uniform cross-section, such as sash weights, washers, pipe flanges, stove lids, etc. Nest molding is also done in snap flasks, the molds being piled on top of one another and the flasks removed. A nest of sash weights that has been made in this manner is shown in Fig. 10 (*b*).

12. Interchangeable Knock-Down Flasks.—Interchangeable knock-down flasks consist of four independent pieces interlocked when put together by means of grooves and tongues and quick-acting clamps. The flasks should be taken apart when not in use, as in this condition they occupy but little space, and they can be conveniently stored in bins or on shelves in the foundry. They are easily assembled, quickly changed from one size to another, and permit a large variety of different sizes to be selected from a comparatively small number of parts.

13. Mold and Bottom Boards.—Mold and bottom boards form a necessary part of the equipment of foundries. They should conform in size to the sizes of the flasks. Each molder requires at least one mold board and as many bottom boards as he produces flasks in one day. The mold boards are usually made of pine; the better grades have hard-wood strips fastened across their ends by means of grooves and tongues. The bottom boards are made of hemlock or pine and have two or more strips fastened across one side, for the purpose of stiffening and holding the single boards together and facilitating their handling. Mold boards can be made of light materials, but bottom boards must be made strong and the large ones should be from $2\frac{1}{2}$ to 3 inches thick. Mold boards are used during the process of molding only; bottom

boards are clamped to the flasks and remain under them until the molds have been poured off and shaken out. Both should be kept in good condition, as it is very important that neither of them become twisted or warped.

CORE ROOMS.

14. Core-Room Arrangement.—The core rooms of jobbing foundries are generally much neglected places. Core

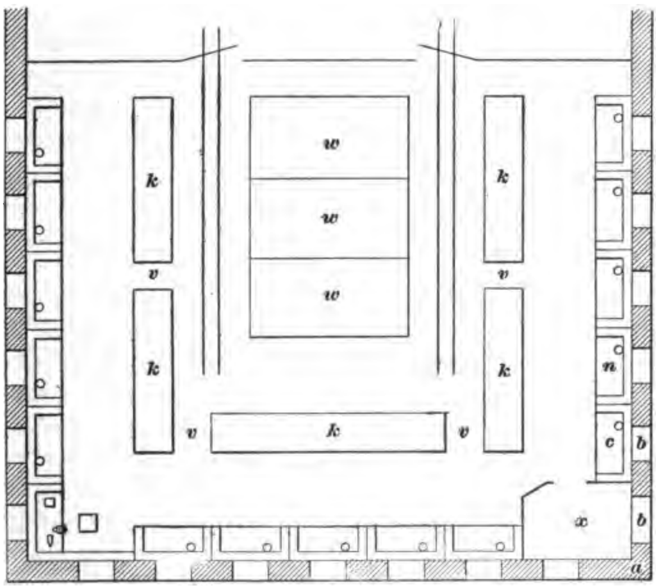


FIG. 11.

making is frequently done in rooms that are poorly lighted, overcrowded, and with very inferior equipment. In large foundries, and especially in those making specialties, the conditions are usually different. The importance of having good cores is here generally more fully recognized, as it is well known that poor cores are a source of considerable loss in molding. Items that may be small in small shops become

large in large shops, and systematic economy and the curtailment of unnecessary expenses are absolutely necessary to financial success. In Fig. 11 is shown the arrangement of a core room. It should, however, be understood that the general arrangement as well as the details depend entirely on existing conditions, and it is not expected that the equipment of any two rooms will be exactly alike. The core room is either a part of the foundry building or an annex to it. Hence, in a modern plant it has substantial brick walls, as shown at *a*, Fig. 11, with a good supply of light through large side windows *b* around three sides of the room. The room should have plenty of overhead air space and be equipped with some standard heating and ventilating system. It should have plenty of floor room for all the machines, benches, ovens, racks, etc., also an office for the foreman. Core rooms in foundries making extra large work are equipped with overhead traveling cranes, jib cranes, or both.

15. Core Benches.—The core makers' benches shown at *c*, Fig. 11, are arranged along the walls in front of the windows, so as to have an abundance of light. Such benches should be substantially built, and have shelves and bins for core rods and wires, and drawers for tools and brushes. The top of the bench should be large enough to hold a liberal quantity of core sand, and be fitted with a planed cast-iron plate. The core sand may be delivered through chutes *n*, which terminate about 1 foot or 18 inches above the benches. Irregular cores are mostly made by hand in special core boxes of wood or metal. The latter are preferable when large numbers of cores are required, as they will keep smoother than the wood boxes and are not so liable to get out of shape.

16. Core-Box Vise.—In Fig. 12 is shown an adjustable quick-acting vise or clamp for holding core boxes while the cores are being made. It is secured to the core-maker's bench *c*; two adjustable clamp screws *b* held in two movable arms *d* grip the core box *a*. Attached to the slide *g* is the

needle *f*, which is used to vent the core *i*. The needle is withdrawn from the center of the core *i* by moving the slide *g* by means of the handle *j*. The clamp screws move outwards and release the core box when the pressure is relieved from the foot-lever *l*.

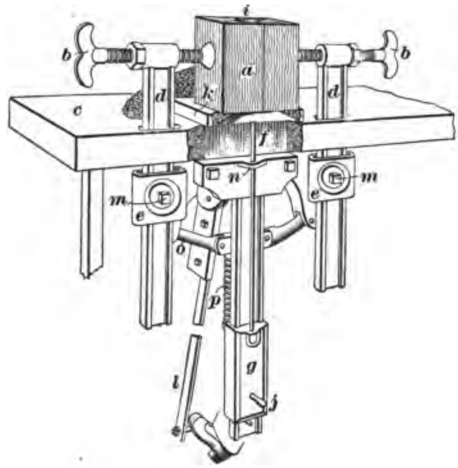


FIG. 12.

17. Core Racks. A core room should have conveniently located racks, shown at *k*, Fig. 11, with ample storage capacity, equally accessible to the core makers and the oven tenders. They are preferably arranged between the core benches *c* and the ovens *w*, with a wide passageway on both sides. These racks consist of a series of open and narrow shelves that permit the cores deposited on one side by the makers to be reached by the men charging the ovens on the other side. This transfer shelf should be of the same height as the benches. The lower shelves serve for empty core plates, and the upper ones for finished cores. The racks should have passageways *v* between them at intervals, to allow free communication between the benches and ovens.

18. Core Plates.—The cores are placed on iron plates and deposited in an oven to be dried and baked. These core plates should have a true planed surface. If warped plates are used for drying the halves of pasted cores, it will be found necessary to rub the faces of the cores together until they make a good joint. But this practice is not to be recommended, as it will be found that such cores are usually out of shape and not true to size, and consequently will not produce satisfactory castings. Core plates should be drilled

with small holes countersunk on the lower side. These will aid both in the ventilating and drying, and decrease the weight of the plates. Cores of irregular shapes are preferably placed on drying plates with outlines of the same shapes as the base of the cores, as this will insure true cores.

19. Core Ovens.—Ovens for drying cores may be either portable or stationary, and consist of iron or brick

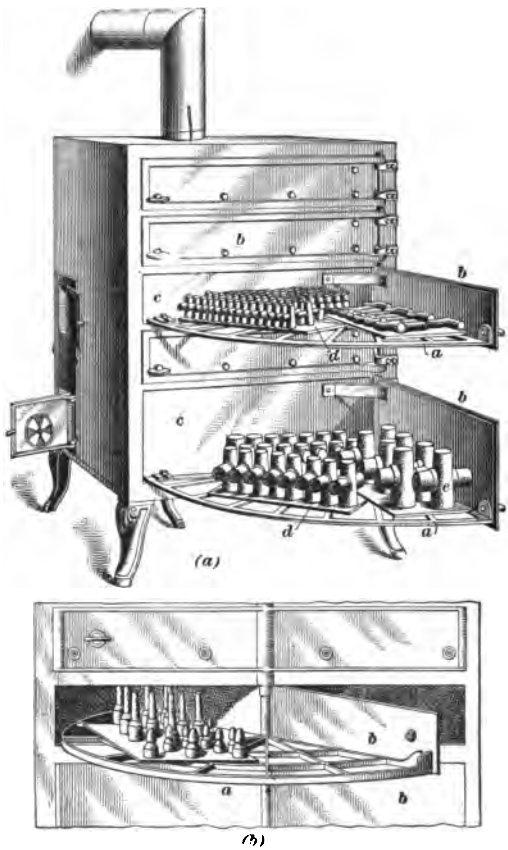


FIG. 18.

rooms provided with racks and shelves, or tracks, and they should be arranged so as to be heated as easily as possible at

an evenly distributed and constant temperature. Ovens are fired with any of the ordinary fuels, but either gas or coke is preferable. A small portable oven is shown in Fig. 13 (*a*). It has shelves *a* fastened to the back of hinged doors *b*. The shelves are cast-iron gratings that allow a free circulation of the heat about the cores *e* that are on plates *d* in the oven. A baffle plate *c*, supporting the shelf and fastened to the door at right angles to it, serves to close the opening and prevent the loss of heat when the door is wide open. In another form of oven the shelf is hinged at the middle, as shown in Fig. 13 (*b*), and the door itself serves as the baffle plate and closes the opening when turned through a half circle from its original closed position. The hinged form of shelf is desirable, as it can be brought into a convenient position to receive the cores or to remove them from it. The body of such ovens is usually of sheet iron made double, the space between the inner and outer walls being either filled with some material that is a non-conductor of heat, or simply a closed air chamber that prevents quite effectively the loss of heat. The furnace is at the rear of the oven, and the flues are arranged so as to distribute the heat evenly to the shelves. The stationary form of oven having either hinged or stationary shelves is usually set in brickwork, and the furnace is located in the bottom or at the side, whichever is most convenient.

20. A stationary oven for drying small and medium-sized cores is shown in Fig. 14. It is made of cast-iron plates bolted together and supported by brickwork. The oven is closed by two hinged iron doors *a*, *a*; the cores *b* are placed on individual plates *c* and deposited on the shelves *d*, which are made of gratings to allow a free circulation of the heat. The furnace *e* is under one end of the oven and enclosed in brick with an ash-pit *f* below the floor. The heat and burned gases pass from the top of the furnace through the openings in the shelves and out the flue *g* at the upper corner of the farthest end. In another style of core oven, the shelves are arranged in the form of drawers equipped with rollers that

run on rails. The outer ends of the shelves, as they are drawn from the oven, are carried by trolleys running on overhead tracks.

For large work the ovens usually have shelves on the sides, and a wide space in the center provided with tracks on the floor to receive iron trucks on which the large cores are deposited; the trucks remain in the oven until the cores are dried. In some cases the trucks are loaded with the

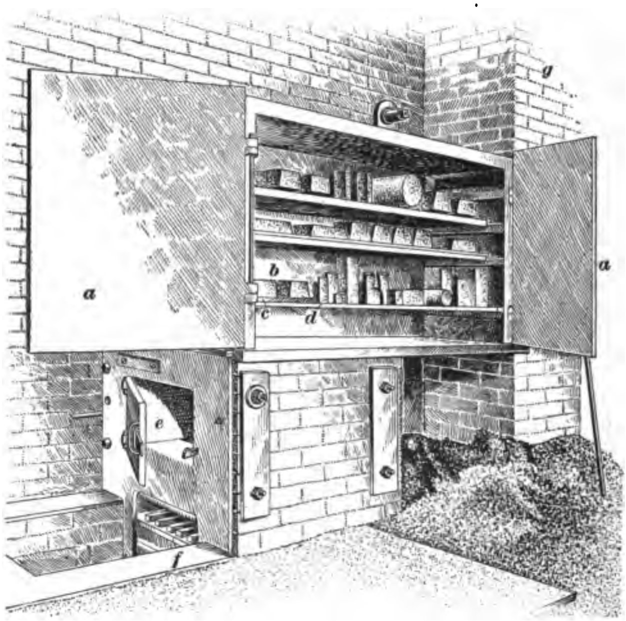


FIG. 14.

cores in the core room, while in others the trucks only move their own length, which is equal to that of the oven, and the cores are transferred to them from other trucks. In the latter case the door may consist of a large plate fastened to the rear end of the truck, which closes the opening automatically when the car is pushed into the oven. A baffle plate on the other end of the car will close the oven when the truck is on the outside, thus preventing the loss of heat.

The cars may be moved either by hand or mechanically. In some cases the doors open by sliding upwards between guides by means of chains and counterweights.

21. Antifriction Trucks.—Some form of antifriction or roller bearings requiring no lubrication is used on the iron trucks used in core ovens. In Fig. 15 is illustrated a truck without journal-boxes that is sometimes used for this purpose. The support for the car frame consists of a casting *a* having two lugs *b*, *b* at the ends, which serve as stops to prevent the axle *c* from rolling off the plate. The proper proportion of the parts should be such that the distance *d* between the center of the shaft in its two extreme positions is to the distance the car is to be moved on the tracks *e* as the diameter of the shaft *c* is to the diameter of the wheel *f*. Some style of antifriction truck is also used in the large core and drying ovens in steel foundries where the entire molds must be dried before the metal is poured. For the heaviest work, especially in annealing furnaces, the trucks are moved on smooth iron balls that are laid in V-shaped tracks, the supporting side frames of the trucks being of a similar form, but inverted so as to fit over the row of balls.

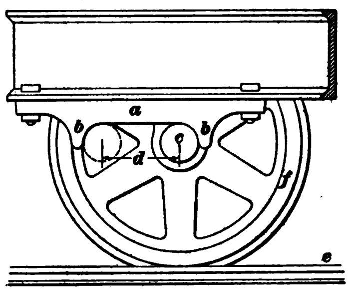


FIG. 15.

22. Machine-Made Cores.—It is only recently that any cores have been made by machinery. The fact that most of the cores are made by hand is, however, no good reason why they cannot be made better and cheaper by machinery, especially those cores with uniform cross-sections. But as yet there is no universal machine suitable for all conditions; it requires a greater variety of special appliances to produce the various shaped cores than it does to make the molds for the castings.

In Fig. 16 (*a*) is shown a machine for making cylindrical and prismatic cores of various uniform cross-sections. The machines are operated either by hand or by power. The machine illustrated consists of a base frame *a* supporting the movable parts and the vertical hopper *b* for holding the

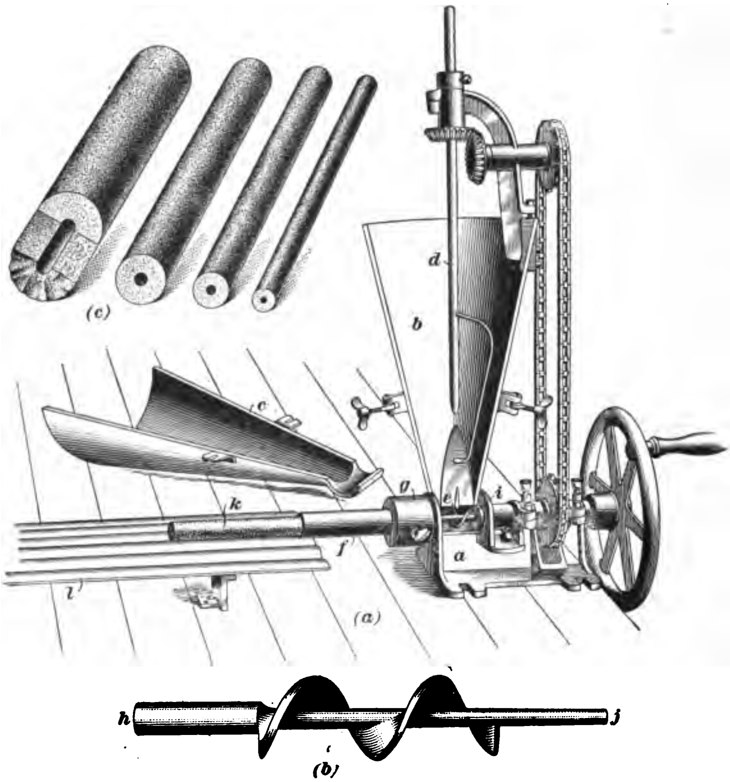


FIG. 16.

core mixture. The hopper is made with the one-half *c* removable, for convenience in cleaning and to aid in adjusting the feeder spindle *d* and changing the bit *e* in the machine. The bit is shown in an enlarged view in Fig. 16 (*b*). A tube *f*, having a hole of the same diameter as the core to be made, is fastened into the socket *g* by means of a setscrew. The machine is supplied with a set of tubes of different sizes

with bits to work with them. To operate the machine, a tube having the desired opening and a bit corresponding to it are selected; the tube is inserted into the socket *g*, and the shank *h*, Fig. 16 (*b*), of the bit is inserted into the socket of the crank-shaft *i*, Fig. 16 (*a*). The point *j*, Fig. 16 (*b*), of the bit extends into the center of the opening in the inner end of the tube *f*, Fig. 16 (*a*). The core material, which should be thoroughly mixed and sifted, is fed into the hopper.

23. The proportions of the mixture used in such a machine may vary considerably. In some work a mixture of the following proportions is satisfactory: 6 quarts of core sand, 1 quart of flour, and 1 gill of raw linseed oil; while for other work as much as 12 to 15 parts of sand to 1 of flour is used. The use of oil enables cores to be kept in stock indefinitely and also lubricates the machines. When the bit is revolved, it forces the material from the hopper through the tube and forms a continuous straight core vented from end to end through the center. The core *k*, Fig. 16 (*a*), is received on a metal tray *l* placed in a horizontal position under the outer end of the tube *f*; the shape of the grooves in the tray should conform to the form of the core. The core is cut into suitable lengths and dried in the oven. Fig. 16 (*c*) shows the sizes of some of the cores made by this machine.

24. Machines are sometimes used for making green-sand cores. The different machines vary greatly, in some cases simply consisting of adjustable boxes various portions of which can be quickly and easily withdrawn from openings in or removed from about the core when it is completed. In some cases special core barrels are also used, and the machines support these while the sand is rammed about them. In reality these green-sand core machines are simply molding machines used for molding green-sand cores, and they may be similar to any one of the several classes of molding machines described in *Machine Molding*.

25. In Fig. 17 is shown a hydraulic core-making machine designed for the production of cores of irregular cross-sections and of moderate sizes, as those required for molding

pipe fittings, cocks, valves, etc. The machine consists of a bedplate with a frame supporting a presser head *a*, a movable table *b*, which supports the molds and is carried upwards by the piston of a hydraulic cylinder *c* and guided by the

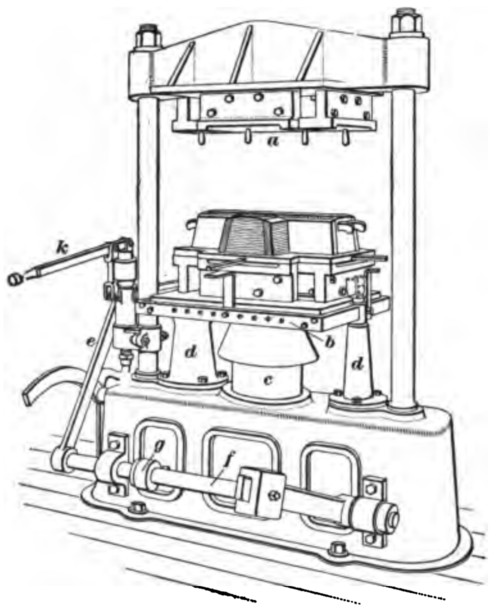


FIG. 17.

two telescope guides *d*, *d*. The table *b*, with the work on it, is raised into contact with the presser head by means of the hand lever *e*, which acts through the shaft *f* and arms *g*. The hydraulic pressure is then applied by means of the lever *k*, and the sand compressed to the desired hardness.

Fig. 18 illustrates the process of making the core required in casting the cock shown in Fig. 18 (*a*), the finished core being shown in Fig. 18 (*b*). The devices used to form this core in the press shown in Fig. 17 are shown in Fig. 18 (*c*). The core is made by first blocking out a body of sand equivalent in volume and approximately of the same shape as the finished core, and then pressing the sand into its final shape. The sand is blocked out by using a matrix *b*, Fig. 18 (*c*), in

addition to the customary half core boxes *a* and *c*, which has an opening corresponding to the outline of the core. The matrix is placed on the bottom half *c* of the core box, as shown in Fig. 18 (*d*), and the sand rammed into the opening. The matrix is then removed, leaving the sand as shown in Fig. 18 (*e*), and the upper half *a* of the core box put in its place and the sand compressed to the form shown in Fig. 18 (*f*). The completed core is shown on the bottom half *c* of the box in Fig. 18 (*g*).

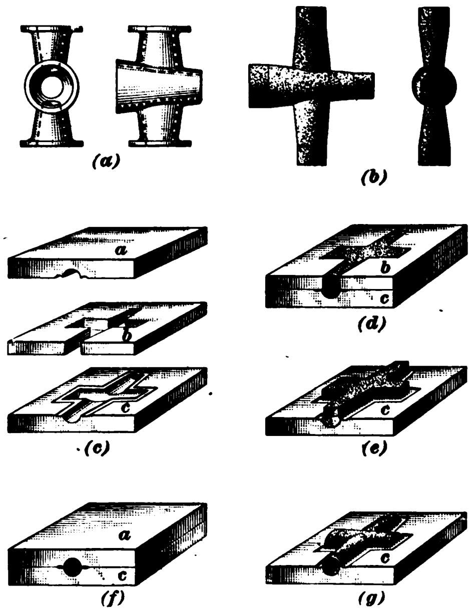
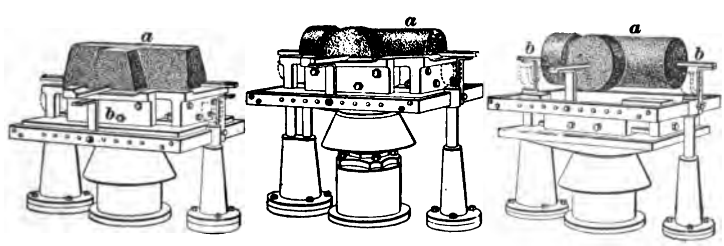


FIG. 18.

Owing to the heavy pressure used, the cores are considerably harder than those made by hand.

The three principal steps in the process are also shown on



(a) (b) (c)

FIG. 19.

the table of the machine in Fig. 19 (*a*), (*b*), and (*c*). In Fig. 19 (*a*) is shown the compressed sand *a* resting on the lower

half of the core box *b* after the matrix has been removed; in Fig. 19 (*b*) is shown the sand *a* after the application of the top half of the core box, and Fig. 19 (*c*) shows the finished core *a* supported by the ends of the stiffening rods *b*, *b*, the lower half of the core box having been removed.

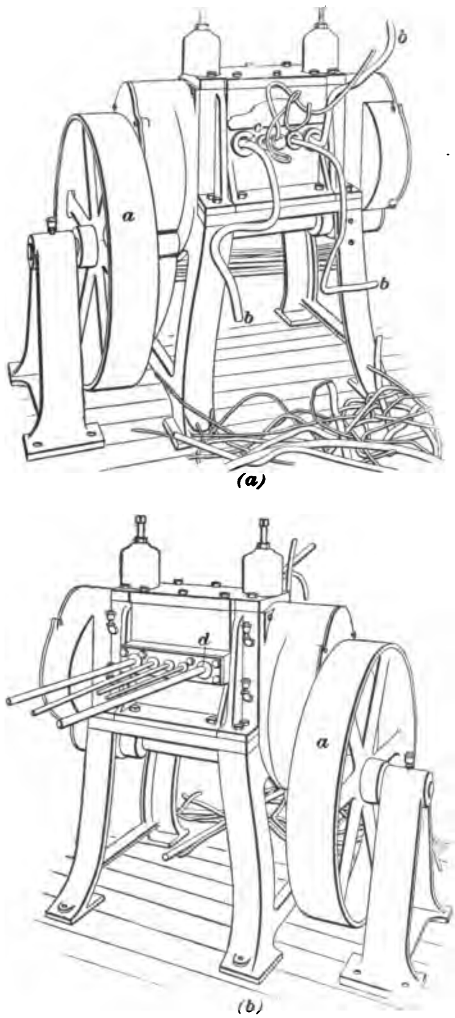


FIG. 20.

26. Core-Rod Straightener. Core rods that have been used are nearly always crooked and in an unfit condition for storing, and it is desirable to have them straightened when they are returned from the molding floor. In Fig. 20 (*a*) and (*b*) is shown a machine designed for this purpose. The body of the machine contains a revolving straightening mechanism that is operated by means of a belt running on the pulley *a*. The crooked rods *b*, *b*, Fig. 20 (*a*), are made to enter the machine through hardened circular bushings *c* and pass out straight through similar bushings on the opposite side of the machine, as shown at *d*, Fig. 20 (*b*).

27. Wire-Cutter.—A wire cutter of the form shown in Fig. 21 is a useful machine for a core room. It consists

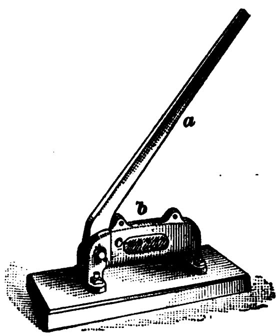


FIG. 21.

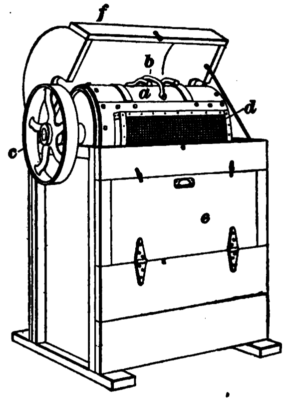


FIG. 22.

of a lever *a* that operates a shear blade *b* and cuts off the wire to any desired length when drawn through the holes *c*.

28. Rosin Grinder.—When rosin is used in core mixtures, it is necessary to prepare it by pulverizing the lumps. A machine for this purpose is shown in Fig. 22 and consists of a cylinder *a* with projections *b* on the outside, and which is made to rotate rapidly by means of a belt on the pulley *c*. The rosin is placed in a box *d* that is open on the inside and fits closely around the lower portion of the cylinder. The pulverized rosin passes through a screen in the bottom of the box *d* and is removed through a door *e*. The frame of the machine is made of wood and is enclosed in a dust-tight case. A hinged lid *f* covers the cylinder.

Another form of rosin grinder resembles a tumbling barrel. It is made of metal and is dust-tight. The lumps of rosin are pulverized in the barrel by means of two pieces of shafting, lying loose on the bottom, that roll against each other as the barrel revolves.

CLEANING-ROOM EQUIPMENT.

29. Methods of Cleaning Castings.—Flasks are shaken out as soon as the nature of the casting permits and piled up or distributed where most convenient for the molders;

the sand is cut up, freed from shot iron and fins, carefully mixed, and tempered ready to be used in new molds. The castings are picked out of the sand, the gates knocked off, and then delivered to the cleaning room. They are then cleaned from all adhering sand, cores and core arbors are removed, and gates and fins are chipped off; afterwards they are tumbled, sand blasted, or pickled, assorted, ground, weighed, counted, recorded, and placed in storage or shipped.

Large castings that are too heavy to be conveniently carried from one department to another are generally cleaned on the foundry floor, where they can be conveniently handled by cranes. The smaller ones are generally cleaned in tumbling barrels, pickling baths, sand-blast chambers, or sand-blast tumblers.

30. Pneumatic Chipping Hammer.—The hand cleaning on the bench and floor is done by means of hammers and chisels, steel brushes, pneumatic hammers, saws, emery grinders, etc. A form of **pneumatic chipping hammer** that is used for trimming castings is shown in Fig. 23 (*a*). It consists of an air cylinder *a* with a reciprocating piston to which is attached a chuck for the purpose of holding a chisel *b*. The compressed air that operates the piston is supplied through a hose attached at *c* at the end of the handle. A valve *d*, operated by the thumb, controls the

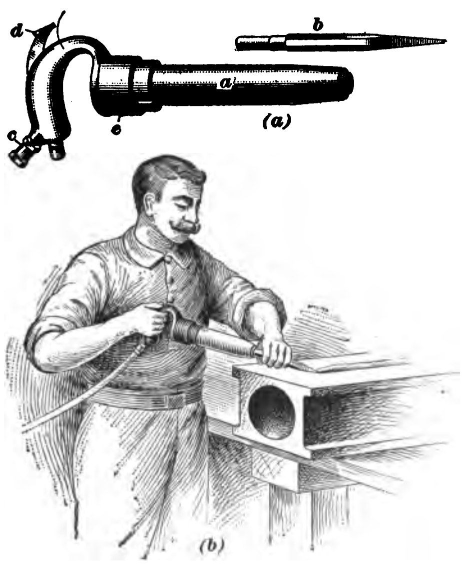


Fig. 23.

admission of the air for the purpose of starting and stopping the hammer. The construction of the hammer is such that the piston serves as a valve to control the admission of the air and its exhaust from the cylinder, and automatically reverses its motion at both ends of the stroke. After forcing the piston outwards, the air exhausts through the holes *e*. The hammer is held firmly in both hands, as shown in Fig. 23 (*b*), and the blows are struck very rapidly.

31. A **flexible-shaft emery grinder** is a very serviceable tool for cleaning castings. If placed on a truck

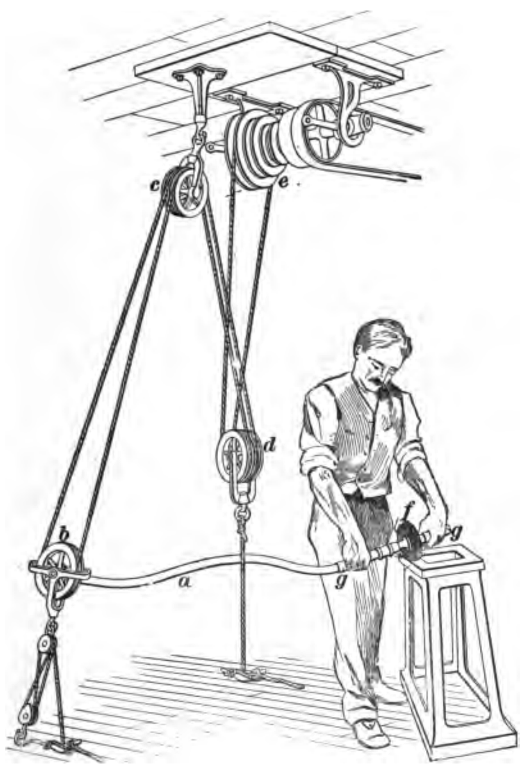


FIG. 24.

and driven by an electric motor, it may be easily taken about the molding floor and used to clean castings in a most

convenient manner. In Fig. 24 is shown a less portable arrangement, but one that is often used. The power is transmitted to the flexible shaft *a* through a rope drive. The pulley *b* may be moved to any location within the reach of the driving rope by changing the length of the rope attaching the idler *d* to the floor. The emery wheel *f* is held against the work by means of the two handles *g*, *g*. The flexible shaft is made by winding successive layers of wire in opposite directions about a center wire, as shown in Fig. 25, the outside being covered with leather.

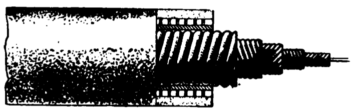


Fig. 25.

32. A **stationary emery-wheel stand** of the form shown in Fig. 26, equipped with two emery or carborundum

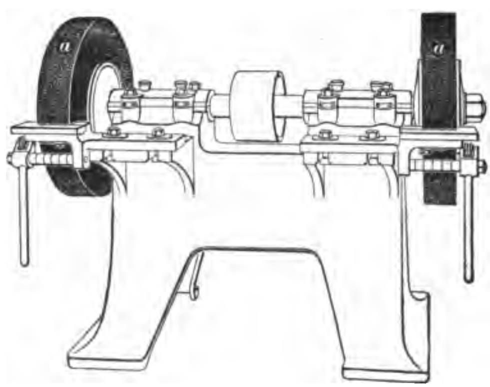


Fig. 26.

wheels *a*, *a*, is used in the cleaning room to remove fins and other small projections from the castings. It is belted to be driven either from above or below the floor. The latter method offers the least obstruction to the operator, as the belt is not in the way and is neater in appearance than the arrangement of overhead belting.

33. Steel brushes in a great variety of forms are used for cleaning sand, scale, etc. from castings and metal work.

In Fig. 27 (*a*) are shown three forms of cleaning brushes to be used by hand. They are useful in cleaning the parts of the castings that cannot conveniently be reached by means of other tools. A rotary steel-wire cleaning brush, which is driven by a belt, is shown in Fig. 27 (*b*). The driving shaft *a* carries a number of steel-wire brushes *b* that pass over the surface of castings held on the table *c*. The table is adjustable and is raised or lowered by means of a foot-lever *d*

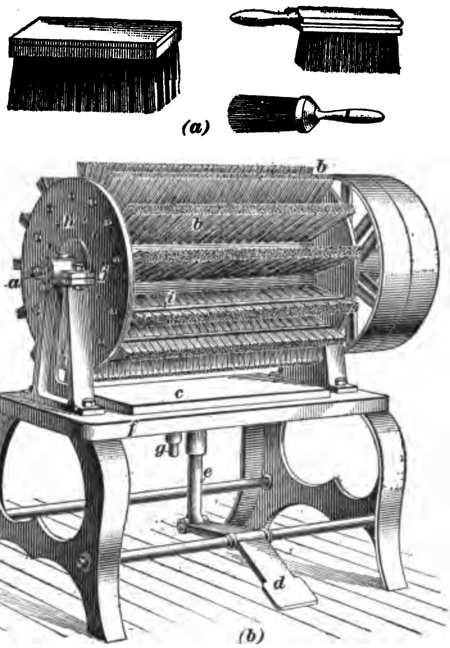


FIG. 27.

hinged to the rod *e* that passes through the frame *f* of the machine and is attached to the under side of the table *c*. The guide *g* aids in keeping the movable table central over the frame *f*. The driving shaft carries two disks *h*, *h* with rods *i* between them running along the rear side of each brush for the purpose of supporting the brushes; these supporting rods increase the life of the brushes considerably. When the

brushes become worn down to the supporting rods, the rods are moved to the inner row of holes *j* on the disks.

34. Machines for cutting gates and sprues from castings are used in the larger foundries, especially in those making brass castings. A belt-driven machine for this purpose is shown in Fig. 28, and consists of a rigid base and frame supporting the working parts, which in this case are in the upper portion of the machine. The sprues are removed from the castings by bringing them between the two steel cutters *a*, the lower one being stationary and the upper one having a vertical motion, produced by means of a lever and a cam on the driving shaft *b*. The pulley runs constantly, and the machine is started and stopped as desired by means of a foot-lever *c* that operates a clutch on the shaft.

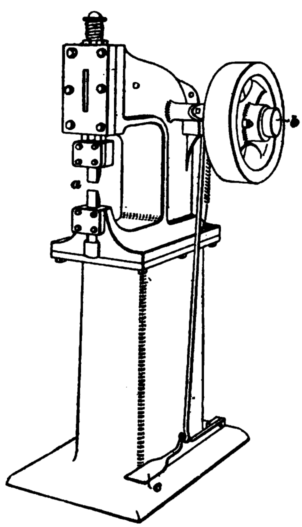


FIG. 28.

35. Sometimes **gate saws** are used to remove the gates from castings. The saws are operated either by hand or power. A band saw for cutting metals, especially brass, is shown in Fig. 29. The machine consists of a frame *a* with a bandwheel *b* driven by a belt on the cone pulley *c*. The saw *d* passes around the band pulley *b* and a similar one *e* held by a vertically adjustable bearing *f* at the top of the frame. The work is held on the table *g*. Guides *h*, *h* are placed both below and above the table for the purpose of supporting the back of the saw when the sprue is pressed against the cutting edge. The top guide has a vertical adjustment. The saw runs at a high speed and is very effective in its work. Hand saws operated by either one or two men are frequently used to remove gates, risers, etc. from large castings.

In foundries using a large number of wooden flasks, a machine for pulling nails from cross-bars is very useful,

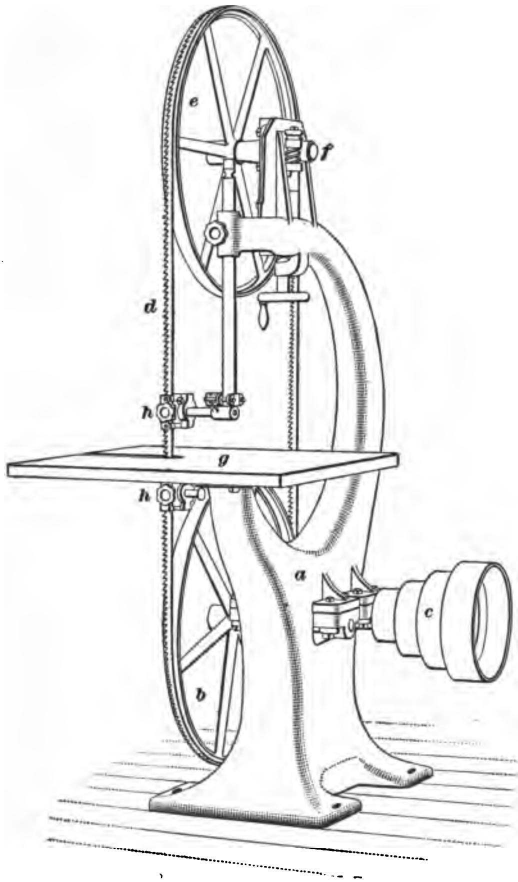


FIG. 29.

especially when combined with a small trip hammer for straightening the nails.

36. Small castings are cleaned in **tumbling barrels,** which are made in a great variety of designs. A plain type

of tumbler is shown in Fig. 30. It is belt-driven, and the heads *a*, *a* of the barrel have gears on their outer rims by

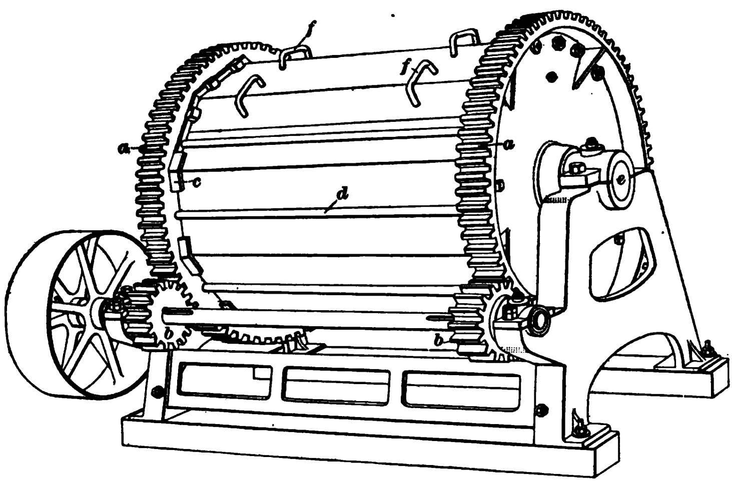


FIG. 30.

means of which motion is transmitted to them from the pinions *b*, *b* on the driving shaft. The staves are held in place by the lugs *c* on the inside of the heads. Tie-bolts *d* bind all parts securely together. The barrel is supported either by trunnions *e* at each end or by a shaft that extends through its center. One or more of the staves have handles *f* and are removable. The barrel is partly filled with castings, and some iron stars, shown in Fig. 31, or blocks of hard iron are added, leaving sufficient space for all the contents to tumble about when the barrel is in motion. The iron stars are sometimes cast with long points, which serve to dig the sand out of corners or holes in the castings. When the castings are thin and easily broken, it is better to use blocks of wood instead of the pieces of hard iron, to avoid breakage. In other cases it is preferable to fasten the castings to the inside of the staves to prevent their tumbling about and

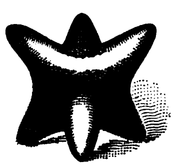


FIG. 31.

damaging their corners and edges. The central space is then partly filled with smaller castings or stars, which, as the tumbler is rotated, clean the surfaces of the large casting. By this method very satisfactory cleaning is done.

37. Tumbling barrels are usually operated in pairs or in rows. In Fig. 32 is shown a row of tumbling barrels that

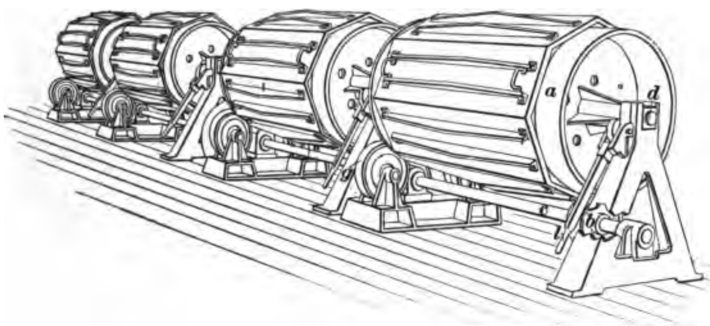


FIG. 32.

are rotated by means of friction rollers on a shaft running lengthwise under the barrels. The end of the barrel forms a flat-faced wheel *a* that rests on a friction roller *b* on the driving shaft *c*. The end of the barrel is kept in line by a cast-iron journal *d* projecting from the head. The bearing of the journal has a vertical movement and is raised or lowered by means of a lever *l*. The rotation is started by lowering the barrel and bringing the friction surfaces of the wheel *a* and roller *b* in contact with each other. The other end of the barrel rests on two antifriction rollers *g*, *g*, as shown in the illustration. Sometimes, however, the end of the barrel is supported by a trunnion that rests either on a bearing or on antifriction rollers supported on a pedestal. A tumbling barrel of this form can be lifted from its support and replaced by another one charged with castings. By having an extra barrel, this system allows the barrels to be filled and emptied on the floor, and the cleaning can go on continuously.

38. The process of dry tumbling causes large volumes of dust in the cleaning room, which is very destructive to the machinery and also makes it impossible for the workmen to remain in the room. To overcome this injurious feature, tumblers are sometimes equipped with an exhaust system to carry off the dust. In Fig. 33 is shown two

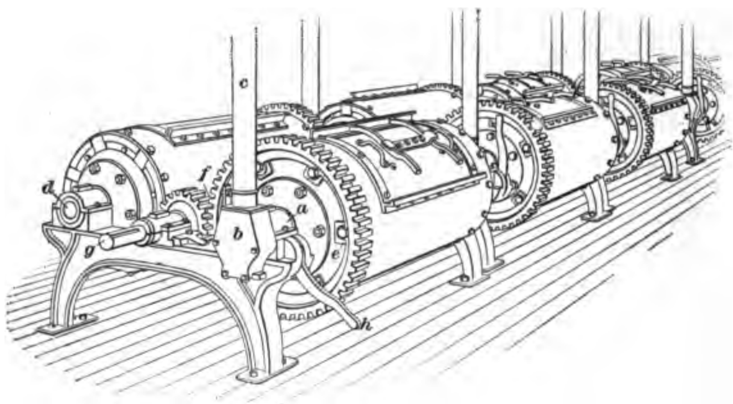


FIG. 33.

rows of exhaust tumblers working in pairs. A hollow shaft *a* at one end of the barrel connects, by means of an enclosed journal-box *b*, with a pipe *c* leading to a fan. The effect of the arrangement is to draw a strong blast of air in through an opening in the other end *d* of each barrel, and the dust is carried through the fan to a flue. Sometimes a water trap is inserted in the exhaust pipe *c* so as to retain as much as possible of the dust and prevent its destructive action on the fan.

The end of each barrel has a gear *e* on the outer edge that is operated from a pinion *f* on the driving shaft *g* extending the full length of the row. Each barrel is stopped and started by means of a lever *h* that moves the bearing of the hollow journal so as to throw the gear *e* on the end of the barrel either in or out of mesh with the gear *f* on the shaft.

39. Tumbling barrels are usually more or less open, and the loose sand, scale, etc. from the castings sifts through to the floor. In some cases the material is removed from the room by means of a **conveyer** running in a pit under the row of barrels. A conveyer suitable for this purpose is shown in Fig. 34 and consists of an endless rubber belt *a* running on idlers placed at intervals along its length. The idlers are arranged in sets of three. Those supporting the loaded part of the belt are arranged so as to give it the form of a trough. The middle idler *b* is horizontal and gives a flat bottom to the trough, while the two outside idlers *c*, *c* are inclined at a suitable angle to form the sides. The three lower idlers *d*, which carry the return loop of the belt, are on a horizontal shaft and the belt is flat.

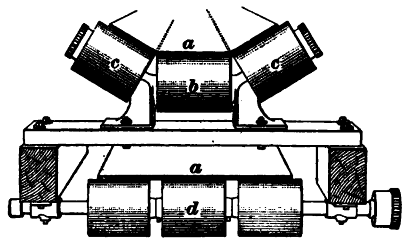


FIG. 34.

40. Oblique tumbling barrels are frequently used for small work. In Fig. 35 is shown a tumbler of this form that is arranged to be tilted and emptied. It is open at the top so that the condition of the castings may be seen during the cleaning process, and any of the castings removed or others added at any time without stopping the rotation of the barrel. The barrel *a* is made either of steel, brass, or wood, depending on the kind of castings to be cleaned. It is supported by a shaft *b* resting in bearings *i* at each end of a frame *c*, which is hinged at *d* and arranged to operate at different angles of elevation by means of a screw *e* and hand wheel *f*. The barrel is tilted for emptying by means of a rack *g* hinged at one end to the rear end of the frame *c* and operated by a gear on the shaft carrying the hand wheel *h*, the shaft being held by suitable bearings on the machine frame *l*. The barrel receives its motion from a friction roller *j*, which is on the shaft carrying the

pulley *k*, and turns against the outer edge of the bottom of the barrel.

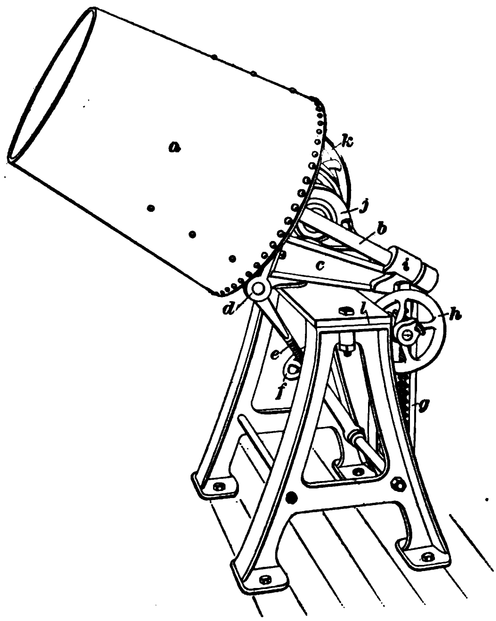


FIG. 35.

41. Brass and bronze castings are preferably tumbled in water. A barrel for this purpose is shown in Fig. 36.

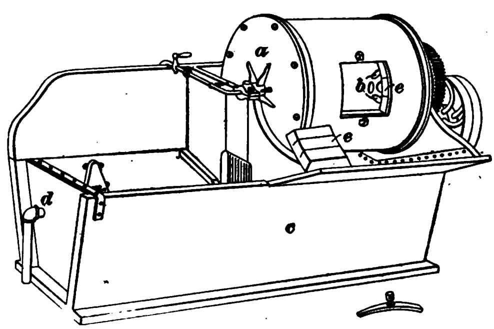


FIG. 36.

The water enters through the center of one head *a* and leaves through openings *b* in the other, carrying the sand

with it. The barrel is mounted over a trough *c* provided with an overflow *d*. The barrel is lined with oak staves *e*. A barrel of the form shown in Fig. 35 is also sometimes used for wet tumbling. Water tumbling barrels are very serviceable in cleaning iron castings and drop forgings that are to be plated, as the process produces a good clean surface.

42. Pickling Castings.—Castings that are to be galvanized, tinned, nickel plated, enameled, or painted should have a perfectly clean metallic surface so that the coating will adhere properly, and castings that are to be machined should be thoroughly freed from all sand to avoid the destruction of tools. Tumbling accomplishes this only with the plainest of castings without cores and with even surfaces. The cleaning of irregular castings can be done more perfectly by pickling or by means of a sand blast. In the pickling processes the castings are treated with dilute solutions of sulphuric or hydrofluoric acids. Pickling solutions for brass are generally prepared by mixing 3 parts of sulphuric acid to 2 parts of nitric acid, and adding to each quart about a handful of table salt. This mixture is used undiluted with water. Although this solution is used for the purpose of cleaning the castings, it leaves them with a good color, and it is therefore used more frequently for the purpose of coloring than for cleaning them. With brass the molding sand does not burn into the casting, and if it should adhere to the surface, it can be easily removed by plunging the castings, while still hot, into water. It is different, however, with iron castings. They must not be cooled suddenly, as this will change their structure, harden their surface, and is liable to crack them. Neither will the sudden cooling remove all the sand from iron castings, as it is often burned into the surface.

43. Sulphuric-Acid Solution.—Dilute sulphuric acid dissolves the iron and loosens the thin layer or particles of sand. Concentrated or strong sulphuric acid has no effect

on the iron, so that it is a mistake to make the sulphuric-acid pickling solution too strong. The solution is prepared by mixing 1 part of sulphuric acid with 4 or 5 parts of water. The mixing should be done slowly, with constant stirring, to avoid accidents, the acid being poured into the water, not the water into the acid. Sulphuric acid must be handled with great care, as it will burn the flesh and clothing. In case of accident, apply ammonia or soda, or wash immediately, using an abundance of water. When the acid is thoroughly cleaned off or neutralized, apply some healing lotion, such as collodion or a mixture of linseed oil and lime water, which should be always kept on hand ready for immediate use. The strength of the bath is easily maintained by measuring occasionally its specific gravity with a hydrometer, and adding more acid when the readings are too low. The solution should be kept in a lead-lined or pitched wooden tank of about 2 feet in depth, which is sunk 12 or 18 inches into the ground, and surrounded by a platform inclining toward the center. It is advisable to provide the bottom of the tank with a wooden grate made with wooden dowels and without iron nails or screws. If necessary, it can be weighted down with lead. This grating will permit the sand and sediment to fall to the bottom and leave a clear solution. A second tank, containing a hot solution of potash or soda, is kept near the first. It is used for a second dip, and its object is to neutralize the acid adhering to the castings; a third tank containing hot water, which is frequently renewed, is used for a final washing of the pickled castings. Castings placed into the pickling solution are usually cleaned in from ½ to 1 hour. If they are too large for the pickling vat, they may be placed on the inclined platform and some of the liquid poured over them from time to time, which will loosen the sand. Sometimes it is preferred to leave the castings for several hours, or over night, in the solution, and in such cases it should be made much weaker than the one first described. One part of acid to 10 or 15 parts of water will make it fully strong enough if used in this manner. This

pickling solution will not work well when cold, and all sulphuric-acid solutions will work best when heated. In order that no acid may remain in the pores of the iron, the castings should be well washed in clean hot water and immersed in an additional bath of a hot alkaline solution, after which they should again be rinsed in hot water.

44. Hydrofluoric-Acid Solution.—Hydrofluoric acid acts in a different manner from sulphuric acid. It does not attack the iron, but dissolves the sand and the underlying oxide of iron. The strength of the solution varies with the time in which the castings are to be finished. A proportion of 1 part of 30-per-cent. acid to 20 parts of water will generally prove satisfactory. If 48-per-cent. acid is used, a mixture of 1 gallon of acid to 30 or 40 gallons of water will give the same results. The solutions should be well stirred and used cold, but it must be kept above the freezing point. It will clean castings in from ½ to 1 hour. Weaker solutions act slower. The bottom of the bath should frequently be cleaned from sediment or the acid will quickly lose its strength by dissolving the loose sand.

Castings pickled in dilute hydrofluoric acid should be rinsed in hot water as soon as removed from the acid. If washed in cold water, they will remain wet for some time and will rust. The addition of some alkaline substance, as lime, potash, or soda, to the hot-water bath will be found very serviceable.

Hydrofluoric acid must be handled with great care, as it will cause painful inflammation if it comes in contact with the skin. An application of dilute ammonia will best neutralize the acid on the skin or clothing. Water should be used freely to wash off the acid. Rubber gloves protect the hands from dilute acid.

45. Sand Blast for Cleaning Castings.—The method of cleaning castings by the sand blast involves the use of an air compressor in connection with an air chamber and a sand reservoir. The process consists of throwing a stream of fine

sharp sand by means of a current of compressed air against the surface of the castings to be cleaned. The rapidly moving sand cuts away all the sand and scale from the castings

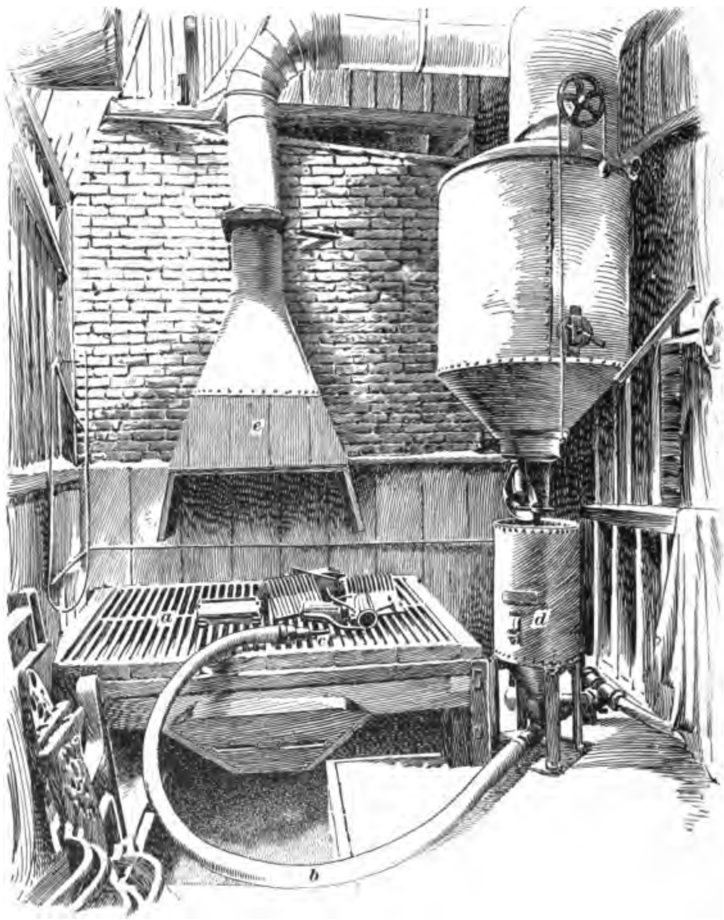


FIG. 37.

and leaves the castings with a clean, smooth surface. The results obtained by this process are better than those of any other method, but it is more costly. Fig. 37 illustrates

a room equipped with sand-blast apparatus for the purpose of cleaning castings. The castings are placed on a grating *a* placed over the opening of a large hopper that directs the sand to a conveyer. A rubber hose *b* terminating in a nozzle *c* leads from the air-pressure tank *d* to the grating. A valve controls the flow of sand and air into the hose. The cutting quality of the issuing stream is so great that it is not a difficult matter to remove lumps and irregularities from the castings. The surfaces of castings cleaned in this way have a white, silvery appearance, and they are in the best possible condition to receive coatings of enamel, paint, or plating. This method of sand-blast cleaning is also applied to structural-steel work to prepare the surface for repainting. The grating *a* is covered by a hood *e* connected with an exhaust fan to draw up the dust. It performs this duty to a slight extent, but not nearly enough to make the application of other safeguards to the operator unnecessary. It is dangerous to the health of an operator to work for any length of time in a sand-blast cleaning room without being protected by a respirator and helmet similar to that shown in Fig. 38. The helmet encloses the head of the operator. It is made of cloth and metal, and has an opening *a* covered by some transparent material, such as fine-wire gauze, celluloid film, or glass. Air is forced into the top of the helmet through a hose *b*, and passes out through the loose portions at the bottom. By making use of these appliances there is little danger to the health of the operator from the dust.

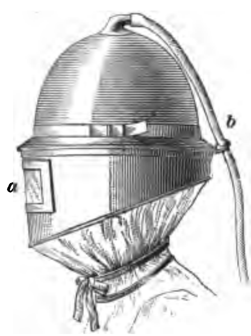


FIG. 38.

46. Sand-Blast Tumbling Barrels.—Another application of the sand blast is shown in Fig. 39 wherein the blast is directed into a slowly revolving tumbling barrel *a*. The castings are placed in the barrel, and the tumbling continually exposes new faces to the action of the blast. The barrel

rotates very slowly, and the method is suitable for light and fragile castings, as there is little danger of breaking them. The sand blast is introduced through the hollow trunnion at one end of the barrel by means of a hose *b* from the pressure tank. After the barrel has been closed, and also further protected by closing the sliding door *c* of the outside case, it is set in motion. When it has been running for from 25 to 45 minutes, the castings are perfectly clean and present bright surfaces and clean edges. The ends of the barrel rest on friction rollers *d* on two shafts that are driven by means of gears *e*, *e* meshing with the worms *f*, *f* on the driving shaft *g*.

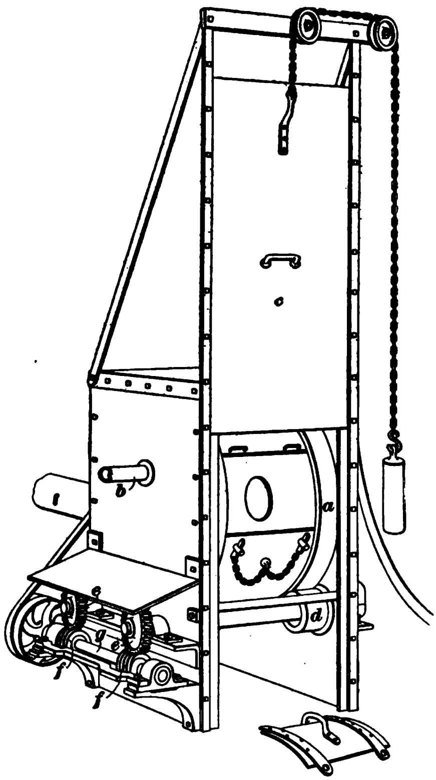


FIG. 39.

47. Cinder Mill.—A cinder mill is sometimes used to remove the iron from the cupola cinder and foundry scrapings. One style of machine for this purpose is shown in Fig. 40 (*a*), (*b*), and (*c*). This mill consists of a sheet-metal barrel *a* supported on hollow trunnions *b*, *b'*, and arranged so that it may be revolved by means of a large gear *c*, on the outer edge of one end of the barrel and a pinion *d* on the driving shaft *e*. A centrifugal pump, operated from the driving shaft *e* by means of bevel gears *f*, forces a stream of

water from a catch basin under the mill into the barrel through the trunnion *b*. The dirt and water are discharged through the trunnion *b'*, Fig. 40 (*b*), into a wheelbarrow having a wire-cloth bottom; the water returns to the pump, the dirt remains in the barrow, and the coke is carried over the barrow and collected by means of a coke screen.

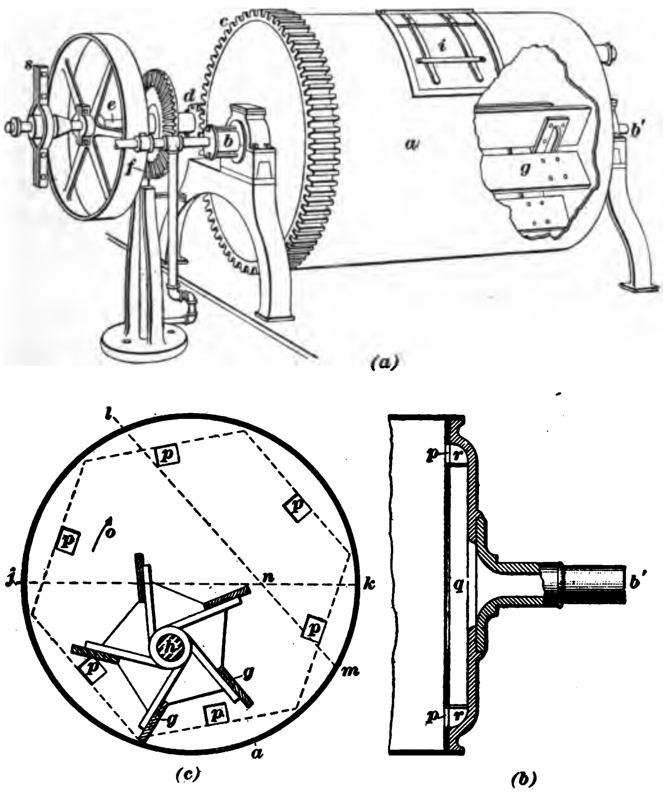


Fig. 40.

The barrel contains a crusher that consists of five pieces of plank *g* attached to a metal frame and shaft *h*, Fig. 40 (*c*). The crusher, whose diameter is slightly greater than half that of the barrel, rests on the bottom of the barrel and revolves when the barrel revolves, by means of the friction

between the shell *a* and the vanes *g*. The material is placed in the barrel *a*, and the iron is removed through the door *i*. When the machine is in operation, the water stands approximately on a level with the center of the barrel, as shown by the dotted line *j k*, Fig. 40 (*c*), and the material is carried around by means of the friction between it and the shell *a* until its surface forms a slope, the angle of which depends on the speed of the barrel, shown by the dotted line *l m*. The water surface line *j k* crosses the cinder slope line *l m* at *n*, thus leaving a channel *k m n* through which the water passes from one end of the barrel to the other. As the mill revolves in the direction of the arrow *o*, the cinder is ground under the vanes *g* of the crusher and carried to the top of the slope *l* and dropped into the water at *n*. The iron and heavy material go to the bottom, while the lighter portions are suspended and carried by the current of water in the channel *k m n* through the ports *p* into the separating chamber *q*, Fig. 40 (*b*). If any heavy cinder enters the chamber *q*, it falls to the bottom and is returned to the barrel through the port *p* above the cinder line *l m*, by means of the buckets *r* attached to the inner edge of the ports *p*. The refuse passes out with the water through the trunnion *b'*. The mill is stopped and started by means of a friction clutch *s* on the driving shaft *e*, Fig. 40 (*a*).

MALLEABLE CASTING.

(PART 1.)

MALLEABLE CAST IRON.

PROPERTIES AND COMPOSITION.

INTRODUCTION.

1. A **malleable casting** is an iron casting of special composition that has been rendered malleable by subsequent continued annealing. The casting, before it is annealed, is very hard and brittle, and as its fracture has a distinctively white appearance, the iron of which it is composed is known as **white iron,** to distinguish it from ordinary cast iron, which has a gray fracture and is known as **gray iron.** The white iron also contains carbon in a form known as *combined carbon*, which will be considered fully later on. In the process of annealing, this carbon is changed to an amorphous, or uncrystallized, form, although not a graphitic carbon found in gray iron, to which the name *temper carbon* has been given. After annealing, the casting can be twisted, bent and hammered, hot or cold, while its strength is more than doubled.

PHYSICAL PROPERTIES.

2. The **tensile strength** of a good piece of melleable cast iron, frequently called simply **malleable,** should lie between 37,000 and 45,000 pounds per square inch. Castings that show 35,000 may be used, and many are made that

run as high as 52,000 pounds per square inch, but this high tensile strength is obtained at the expense of resistance to shock. These high results are secured by adding from 2 to 5 per cent. of steel scrap to the regular mixture in the open-hearth furnace.

3. Ductility.—The elongation of a malleable casting should lie between 2.5 and 5 per cent.; the thicker the piece, the smaller is the elongation. Tests are usually made on bars .8 inch in diameter, not turned down, and the elongation measured by pricking center-punch marks along the whole bar at intervals of an inch. After the bar has been pulled apart, the two parts are fitted together and the extension measured between the two marks on both sides of the mark nearest the fracture, which were originally 2 inches apart.

4. The **transverse,** or **bending, strength** of a malleable casting should be such that it will carry a load of between 3,500 and 5,500 pounds, the load being applied at the middle of a bar 1 inch square, supported at its ends, upon supports 12 inches apart. The deflection from the horizontal should be at least ½ inch, but very good and soft iron often gives a deflection of 2½ inches.

5. The **resilience,** or resistance to shock, of the average malleable casting is about 8 times that of cast iron and half that of steel. This is true for powerful shocks not often repeated. For continued light shocks, as in railroad service, a malleable casting is superior to one made of steel.

6. Effect of Temperature of Molten Iron.—In making the hard castings, that is, before they are annealed, it is necessary to have a white fracture, or only mottled very slightly, otherwise the annealing will spoil the work. In order to obtain a white fracture the iron must be chilled in the mold. It is known that thin sections chill much more quickly in the sand than thick ones; a thin piece may therefore set at once and show a perfectly white-glass hard fracture. The same iron, however, if run into a section, say,

2 inches thick, will cool slowly and result in a perfectly gray casting. This gray casting when subjected to the annealing process will come out "rotten," being burned and disintegrated throughout.

The temperature of the melted iron, or bath, must also be observed. A hot iron chills better than a comparatively cold one. Thus, a casting 1½ inches thick may be poured from the hottest part of the bath and have a white fracture, while the same casting poured from the first of the tap, or the coldest iron, may be perfectly gray. If the iron is dull, therefore, all the thin castings that can safely be run, should be poured; if the iron is very hot, the lightest work should be poured first to avoid spoiling the work; the heaviest should be taken next, and finally the medium-weight castings should be poured.

While it is essential to have the iron at a suitable temperature for the castings to be poured, care must be taken not to prolong the heat more than is necessary, as long-continued heating causes changes in the composition of the bath by carrying off the silicon and carbon.

7. The **contraction** in hard castings is approximately ¼ inch to the foot. As, however, in the annealing process some of this is restored in some cases as much as one-half, the ordinary shrink rule for gray iron is frequently used for patterns for malleable work also. It is well, however, to keep close watch of the behavior of the various castings that are made in quantity, and to have the patternmaker correct the pattern for any variations that are noticed regularly. It is recommended by some engineers that an allowance of $\frac{3}{16}$ inch per foot be made for all patterns, and that after a trial such alteration be made as may seem necessary from the castings thus produced.

8. **Shrinkage** in hard castings must be carefully watched. Wherever there is a thin flange next to a heavy section, the thin part solidifies first, and draws away the metal, which is still fluid or plastic, from the heavy mass next to it, resulting in a hole or spongy spot in the thick

portions of the casting. The same is true of a sharp angle; there is generally a line of spongy iron just where it should be strongest. This is not to be wondered at, as the excessive shrinkage of white iron makes it much more difficult to get sound malleable castings than gray-iron ones. The means of prevention are the use of fillets wherever possible, the application of chills of gray or white iron in the worst places, and care in making and handling the mixture.

CHEMICAL COMPOSITION OF MALLEABLE IRON.

9. Elements Contained in Malleable Iron.—The elements found in malleable cast iron are the same as those in gray iron, but vary in quantity and in their distribution. The composition of good malleable iron should be within the limits indicated in the following table:

Silicon	.35 to 1.25 per cent.
Manganese	.15 to .30 per cent.
Phosphorus	.08 to .25 per cent.
Sulphur	.02 to .07 per cent.
Total carbon	1.50 to 4.20 per cent.

All other elements remaining between the limits given, the variation of the silicon must be closely watched; .35 per cent. is used for the heaviest casting of thickest section, and 1 per cent. for the lightest work. In average practice the percentage of silicon usually lies between .5 and .7 and the total carbon is sometimes even lower than 1.5 per cent.

10. Silicon is the most active agent in the malleable mixture. A bath of iron having 1 per cent. of silicon and other ingredients normal would make good white castings $\frac{3}{8}$ inch thick or less, mottled castings up to $\frac{1}{2}$ inch thick, and be liable to make gray ones in thicker work. A bath with .35 per cent. of silicon will make a piece even 2 inches thick nearly white, if cast hot enough, and would be suitable for all castings were it not desirable to make smaller work with a higher percentage of silicon owing to the difficulties

encountered with cold iron and excessive shrinkage. For coupler work, therefore, the bath should contain from .35 to .55 per cent. of silicon; for ordinary castings averaging ½ inch in thickness, from .45 to .75 per cent., preferably .6 per cent.; for pipe fittings and agricultural work, from .75 to 1 per cent., preferably .8 per cent.; and for saddlery, hardware, scissors, and the lightest castings it may contain from 1 to 1.25 per cent.

Samples of iron should be furnished the laboratory for the purpose of determining the percentage of silicon of the heats. These samples should be taken from about the tenth ladle, and again at the end of the heat. The iron for these is poured on a stick of wood laid across a pail of water, and made to run from the stick into the water. This causes it to form into small spherical drops, resembling shot, and is said to *shot* it. The water should be thrown off quickly, and the sample dried in a hot ladle, thus leaving clean dry shot, which is then pounded fine in a steel mortar, by the chemist, and the silicon determination made.

11. Manganese.—Of the various constituents of a bath of iron, manganese burns out first. Pig irons seldom contain more than .8 per cent. of manganese, and this is reduced to from .15 to .3 per cent. in the casting. Too much manganese in the mixture should be avoided, as the expense involved in burning it out is quite great. The excess of manganese is paid for as iron, and .5 per cent. burned out means in itself a loss of 7 to 10 cents a ton. Manganese, also, in burning out, protects the silicon for a time, thus prolonging the heat, and if the temperature is high enough, it helps to remove the sulphur. If present in too great a quantity, say about 1.5 per cent., it hardens the iron and causes trouble in the annealing. For these reasons it is advisable in purchasing pig iron for a malleable-iron foundry, to specify that it shall have from .5 per cent. to .6 per cent. of manganese, and refuse all containing over .8 per cent. unless it is to be mixed with other irons low in manganese. Iron high in manganese may, however, in the absence of other iron, be

used without mixing with irons low in manganese, by skimming the bath frequently and allowing the manganese to burn out. The purpose of the skimming is to maintain a clean surface so that the manganese may be freely oxidized.

12. Sulphur, which is generally known as the enemy of the founder, is a very important factor in the malleable-iron industry, and special efforts must be directed toward keeping it out. In the days of charcoal irons this was easily done, but at the present time blast furnaces making Bessemer iron try to dispose of their bad casts (generally known as *off casts*, or *off heats*) to malleable works, so that too great care cannot be exercised in the purchase of iron. When a blast furnace is not working well, scaffolds—masses of ore, fuel, and flux that bridge over the furnace—form, the limit of .1 per cent. of phosphorus is exceeded, and the sulphur goes above .05 per cent., so that the steel makers cannot use it. In fact the sulphur will be found to be .09 per cent. more often than .05 per cent., and if this material is used in the malleable foundry, serious trouble results in annealing, and even in the foundry. It is therefore advisable to insist on having the analysis of irons for sulphur made by the oxidation method, as this method accounts for all the sulphur in the iron; the easier evolution methods, used by many chemists, often miss as much as half the sulphur present. Sulphur so weakens the iron that it is not able to resist the internal strains always present in the hard castings, and cracked castings are produced. The cracks in the hard casting are before annealing often visible only under the microscope, but they are brought out by the annealing process and subsequent finishing. Sulphur furthermore increases the difficulty in annealing. It makes it necessary to subject the castings to a higher temperature and to maintain the heat for a longer period, which in turn causes greater damage to the castings. Good castings have been made with .1 per cent. of sulphur, but this is the exception and not the rule. It is best to use irons that contain not more than .04 per cent. of sulphur, and preferably not over

.02 per cent. When the mixture contains .05 per cent. of sulphur, or over, it may be smelled at the spout of the furnace.

13. Phosphorus seldom causes trouble in the manufacture of malleable iron, as the irons ordinarily bought do not contain more than .175 per cent.; charcoal irons, however, often contain more than .2 per cent. Iron containing more than .25 per cent. should not be used, for the castings are liable to be cracked and warped; besides they will be unable to resist the heat of the annealing oven. The melting point of the iron is lowered by the presence of much phosphorus, and it will therefore oxidize considerably in annealing.

14. Carbon.—In malleable-iron work three forms of **carbon** must be dealt with—*combined carbon*, *graphitic carbon*, and *temper carbon.*

Combined carbon is carbon that has entered into chemical combination with the iron. It is subdivided into three or four forms, but these do not interest the malleable-iron founder. Hard castings should have all their carbon in the combined form. The fracture of this class of iron is white, somewhat resembling the color of silver, shows distinct crystallization, is as hard as tool steel, but is very brittle. The amount of combined carbon in malleable castings varies between 1.5 and 4.2 per cent. When charcoal iron was generally used, and it is still used in some sections, as in the Lake Superior region, 4.2 per cent. carbon was very common. The advent of coke irons into the field, however, caused a drop in this element, which drop has since been increased by the addition of low-carbon steel clippings to the mixture. The percentage of combined carbon cannot run much above 4 2 per cent., as the iron is then nearly saturated with carbon; but on the other hand, it must not be allowed to fall below 1.5 per cent., otherwise the castings will not anneal properly. A sharp crystalline outline is an indication of good iron; a mushy, indistinct structure usually means weak, oxidized, unfinished metal.

15. Graphitic carbon in a malleable casting is undesirable because it opens the structure; this causes the

oxidation in annealing to penetrate the iron and weaken it. If the amount of graphitic carbon present is sufficient to make the fracture of the hard casting so mottled that it shades into a light gray, the annealed piece will come out weaker than if it were an ordinary gray casting. Attention to the percentage of silicon, temperature of the bath, and details of pouring, will, however, avoid this trouble.

16. The name **temper carbon** was given to this form of carbon by Professor Ledebur, a German authority, who finding it only in malleable castings, which in German are called *tempergus*, called it "temper" carbon. It is only produced by converting into pure carbon the combined carbon of white castings. In doing this, the casting expands, frequently, about one-half of the original contraction in cooling in the mold. A network of soft steel is formed around the particles of carbon and acts as a cushion to blows and allows the piece to bend. The iron itself, being combined with nearly 4 per cent. of carbon, now becomes freed of about 3½ per cent. of it and therefore becomes a steel. The malleable casting is then really a piece of soft steel, but with about 3½ per cent. of carbon placed between the chains of crystals of iron, weakening it correspondingly, but leaving it twice as strong as cast iron. Temper carbon is not present in flakes like graphitic carbon.

The annealing process effects this remarkable change, which goes on whether the castings are packed in an oxidizing medium or in sand or fireclay. While the total carbon is distributed evenly in the hard casting, it is not so in the annealed piece. There is a removal of carbon from the skin of a malleable casting, which extends inwards about ¼ inch. Herein a difference between American and European practice exists. In American practice the annealing process is continued only until the combined carbon is changed to temper carbon, while in Europe the annealing is continued until the greater part of the carbon is removed; this can be done only with thin castings, the fracture of which will look like a piece of broken wrought iron. American castings

have a velvety-black interior, a light-gray band at the surface, and a thin white skin; for this reason Europeans call American malleable castings *black heart.*

IRONS USED IN MAKING MALLEABLE CASTINGS.

17. The **pig irons** used in malleable-iron castings may be either charcoal or coke irons. Charcoal irons are the best, owing to their greater freedom from oxidation. In other respects coke irons make equally as good malleable-iron castings.

Charcoal pig irons used for this work are all made by the warm-blast process, the cold-blast iron being entirely too expensive. Charcoal irons are used now only in the Lake regions where the blast furnace is near the foundry, and freight charges are not too great. The cost of the charcoal irons is higher than that of the coke irons and the latter are therefore generally used, except in localities where the difference in cost is offset by the relative freight rates, or other conditions that may enter into their use. When charcoal irons are used they are usually of grades running from No. 1 down to No. 6. Nearly all these irons are now sold by analysis, and the following table will show the percentages of silicon usually found in each.

TABLE I.

AMOUNT OF SILICON IN CHARCOAL IRON.

Grade of Iron.	Percentage of Silicon.	Grade of Iron.	Percentage of Silicon.
1	1.25 to 1.50	4	.50 to .75
2	1.00 to 1.25	5	.30 to .50
3	.75 to 1.00	6	.10 to .30

In the market, each number has three subdivisions, as, for instance, No. 2 soft, No. 2 medium, and No. 2 hard. In

the table, the upper limit of silicon corresponds to the soft, the lower to the hard, and a point midway to the medium. These grade numbers are, however, gradually disappearing, and for malleable purposes coke irons, having been introduced by trained metallurgists, are bought only by analysis.

18. Many malleable works have stocks of all numbers constantly on hand. This is not necessary, for the higher numbers are used only in case the castings come out a little gray. With well-regulated mixtures for light work, such as agricultural castings, the stock in the yard should be about as follows: Pig iron running 1.5 per cent. silicon, one-eighth of the entire stock; 1.25 per cent., one-half of the stock; 1 per cent., one-fourth of the stock; the remainder should have .75 per cent. silicon. For the heavier grades of castings the relative proportion of irons containing 1.25 and 1 per cent. of silicon are reversed. A stock book should be kept and the quantities of iron required, which quantities are determined by experience, ordered periodically, so that no shortage may occur at a critical moment.

19. Coke pig iron is known in the market under various names—malleable coke and malleable Bessemer are the most common. The malleable coke irons are made especially for the malleable-iron trade and are usually very good. Malleable Bessemers are unsafe, as they are usually made up of bad heats, as has already been explained. When making a test of a given grade of iron, the mixture should contain as much of the iron on trial as possible; the gates from the heat should be kept separate, and also the bad castings. Another heat should then be made with the same mixture and the test bars broken. If the results are up to the average, it is advisable to buy the iron; but if the results are not up to the average, it should not be bought.

The specifications for the four varieties of pig iron kept in stock, whether charcoal or coke, should be as follows: Silicon, (*a*) 1.5 per cent., (*b*) 1.25 per cent., (*c*) 1 per cent., (*d*) .75 per cent.; manganese, not over .8 per cent. for all grades; sulphur, not over .04 per cent. for all grades;

phosphorus, not over .225 per cent. for all grades. In some cases, however, the percentage of manganese is made as low as .4 per cent. instead of .8. Specifications for carbon are not necessary, and it is desirable to get the sulphur as low as 20 per cent., if possible, and the phosphorus down to .1 per cent. A leeway of .05 per cent. of silicon is allowable either way. In piling the iron in the yard, it is advisable to spread a car load in line on the ground, then spread each successive car load of the same analysis on top. In using the iron, it should then be drawn from the end of the pile. In this way a good average of the iron is obtained, poor car loads are mixed with good, and the composition is kept uniform.

20. The **scrap** produced in the malleable-iron foundry is of two kinds: *hard*, or *unannealed*, *scrap*, which includes the gates and scrap castings that come from the trimming room, and *malleable scrap*, or annealed material from the finishing rooms, and that bought, or for which good castings have been exchanged.

Hard scrap should be tumbled in the tumbling barrels to clean off all the foundry sand that may adhere to it; this saves fuel in melting and leaves the bath cleaner. It is important to have this scrap, or **sprues,** as it is called in malleable-iron foundries, well mixed; that is, if two or more heats are made, the scrap from all these should be well mixed, because if any one heat should be burned, the scrap from it, if it went entirely into one heat, would spoil that also. When scattered through the scrap of several good heats, however, the bad effects are reduced and eventually disappear.

Annealed scrap, which has in the past only been fed into the cupola with the iron for pots for annealing purposes, is now very extensively used in making malleable iron. When the malleable scrap is very rusty it should be fed into the pot mixture, as it might cause trouble by forming pinholes in the surface of malleable castings.

Steel scrap is composed of plate shearings, old files, shafts—in fact any kind of steel scrap in pieces weighing not over 250 pounds. It is generally added to the mixture, but in some cases the market value of such scrap is so high that

it can be sold and other materials purchased at prices that will enable malleable iron to be produced more cheaply.

21. Ferrosilicon is a combination of iron and silicon, with small percentages of other impurities. It is sometimes looked upon as an iron running extremely high in silicon. A car load of this useful material, which may contain from 8 to 14 per cent. of silicon, should always be kept on hand. It often happens that the furnace works badly, and the heat must remain in the furnace longer than it ordinarily should. The long-continued heat burns out much of the silicon and causes the absorption of gases to such an extent that the iron is ruined for all casting purposes. The addition of from 150 to 500 pounds of ferrosilicon, well stirred, or rabbled in, will, however, save the heat, although the castings made are not so strong. The heat may also be run into pigs, and used subsequently with the sprues.

IRON MIXTURES.

22. Classification of Malleable Mixtures.—The mixtures used in malleable-iron casting depend on the melting process. There are three of these processes in use in American practice: the *cupola*, the *coal*, or *air*, *furnace*, sometimes called the *straight-draft furnace*, and the *open hearth*. A fourth process, known as the *crucible process*, is no longer used in America, being very expensive, although in Europe a large part of the malleable castings are still made by it.

23. Cupola Mixture.—The mixture for the **cupola process** is probably the easiest to keep in good condition, as the amount of silicon burned out is quite constant, and amounts to about .25 per cent. If it is desired to hold .6 per cent. of silicon in the castings, and this is usually the case in work to which the cupola process is adapted, the mixture that enters the cupola must contain about .85 per cent. of silicon.

24. Coal-Furnace, or Air-Furnace, Mixture.—With this process there is also very little trouble in connection

with the mixture, unless the blast gives out or the fires are not properly attended to. As this is seldom the case, care must be taken to provide only as much silicon as is required in the casting and the amount burned out; the latter usually amounts to about .35 per cent., but depends in part on the manner in which the furnace is run. In order to get castings with .5 per cent. of silicon the mixture must contain .85 per cent. of silicon when it enters the furnace.

25. Open-Hearth Mixture.—The mixture for the open-hearth furnace requires the closest attention. The product of this type of furnace is superior to that of other types, but the process is more liable to irregularities. The amount of silicon burned out is from .3 to .4 per cent. when normal, and may occasionally run up to .75 per cent. It is therefore well to have a supply of ferrosilicon in a box close to the furnace to add to the bath, if necessary, but it should be used only when absolutely necessary. There is at times a temptation for the melter to let the heat drag along without exerting himself to keep it rabbled up, and then cover up this lack of attention on his part by the addition of ferrosilicon.

26. Calculation of the Malleable Mixtures.—The first step in calculating the proportions of the mixture is to proportion the pig iron to the scrap. In normal malleable practice equal quantities of these are used; where much heavy work is made more pig iron is used; and for very light work more sprues are required. It is not good policy to have more than 70 per cent. of pig iron in the mixture, as otherwise the castings will be weak; if more than 70 per cent. of sprues are used, there will be trouble from excessive contraction, cracking, and incomplete annealing.

Suppose 50 per cent. of scrap is to be used; this may be made up of 45 per cent. of hard sprues and 5 per cent. of malleable scrap, or where the open-hearth process is used 25 per cent. of hard sprues and 25 per cent. of malleable scrap may be used, the remainder of the mixture, 50 per cent., being pig iron. For purposes of calculation, malleable scrap may be assumed to contain .4 per cent. of silicon. The

percentage of silicon in the sprues is known from day to day through the laboratory; let us suppose for illustration, that it is .5 per cent. Next the greater part of the pig iron is selected from the stock of which the largest quantity is on hand, say iron with 1 per cent. of silicon. The remainder of the mixture is made up of a pig iron that will supply the remainder of the silicon required. The amount of the latter may have to be determined by trial, especially if the iron that would just give the required composition is not at hand.

The calculation for a charge of 20,000 pounds for a 10-ton heat in the coal furnace is made as follows: Assuming that 9,000 pounds of sprues and 1,000 pounds of malleable scrap are used, we have

	Pounds.	Per Cent. of Silicon.	Total Silicon. Pounds.
Sprues	9,000	.5	45
Malleable scrap	1,000	.4	4

If there should be on hand a good stock of Mabel iron, running 1 per cent., and Briar Hill running 1.25 per cent. of silicon, these may be taken in the following proportions:

	Pounds.	Per Cent. of Silicon.	Total Silicon. Pounds.
Mabel	5,000	1.00	50.0
Briar Hill	3,000	1.25	37.5

There are still 2,000 pounds to be provided. To find out what can be used it is necessary to see how many pounds of silicon are needed to give .85 per cent in the final mixture. This, for 20,000 pounds, would be 170 pounds. Adding the amount of silicon already provided, we have 136.5 pounds, leaving 33.5 pounds to be furnished by 2,000 pounds of pig iron, which must therefore have a percentage of about 1.7 silicon. As there is no pig iron with

this high percentage of silicon in stock, it is necessary to reduce the Mabel and increase the Briar Hill. The object is to leave just enough silicon to be provided for by something that is in stock. By trying a few times, it is found that 3,000 pounds of Mabel and 6,000 pounds of Briar Hill will give proportions of silicon that can be used, as indicated by the following calculation:

	Pounds.	Per Cent. of Silicon.	Total Silicon. Pounds.
Mabel.............	3,000	1.00	30
Briar Hill.........	6,000	1.25	75

When added to the original 49 pounds from the scrap, this will give 154 pounds of silicon out of the 170 required. This leaves 16 pounds of silicon and 1,000 pounds of iron yet to be provided. Seneca iron with 1.5 per cent. of silicon will supply approximately these amounts. Using the Seneca iron, the mixture would now be as follows, which gives .845 per cent. of silicon:

	Pounds.	Per Cent. of Silicon.	Total Silicon. Pounds.
Sprues............	9,000	.50	45
Malleable scrap....	1,000	.40	4
Mabel.............	3,000	1.00	30
Briar Hill.........	6,000	1.25	75
Seneca............	1,000	1.50	15
Total.........	20,000		169

The open-hearth mixture is calculated in exactly the same way. In both cases 100 pounds steel can be thrown in without upsetting the calculations. In the cupola mixture the method outlined above is also employed. Here, however, it is necessary to deal with small charges of, say, 2,000 pounds each, these being charged into the cupola with layers of

coke between them. The charging is done as in the gray-iron foundry, with the exception that in malleable practice the amount of coke charged should be double that used for gray iron, or 4 pounds of iron to 1 pound of coke, instead of 8 pounds of iron to 1 pound of coke. This is necessary to insure iron hot enough to run the light castings to which this process is alone adapted.

27. Pot Mixture.—One of the large items of expense in a malleable foundry is met with in the maintenance of the annealing pots. The pots last from four to twenty heats, depending on their composition. As they are wasted away during the process of annealing, they are practically a dead loss, and as the average pot weighs 300 pounds this forms quite an important item.

As it is essential to have an iron with a high melting point and at the same time as refractory as possible, it must be pure and free from graphitic carbon. It is therefore advisable to use the regular malleable metal whenever there is too much made, and more than enough sprues for the regular mixture are produced in the regular day's run. As, however, this would not give enough pots to last the annealing room 1 day in the week, it is necessary either to increase the charge of the furnace and use the regular malleable mixture, or to run a cupola especially for this purpose. The pot mixture when melted in a cupola is made up of the pig irons used for malleable castings, and as much malleable scrap as it will carry, as high as 75 per cent., if necessary. The silicon should be .6 per cent., and such a mixture would consist of, say:

	Pounds.	Per Cent. of Silicon.	Total Silicon. Pounds.
Malleable scrap....	3,000	.40	12.0
Mabel............	1,000	.75	7.5
Briar Hill.........	2,000	1.00	20.0
Total.........	6,000		39.5

The average amount of silicon in this mixture is .66 per cent.

It is not advisable to remelt the old pots, as they are too heavily oxidized. Pieces of iron too large to be charged in a furnace, commonly called *salamanders*, when broken up small enough to go into the charging door of the cupola should, however, be utilized.

28. Pill-Heat Mixture.—Another mixture used in the malleable-iron industry, when the open-hearth process is employed, is called a **pill heat.** It is used when it is necessary to cut down the bottom of the furnace or hearth. About 3,000 pounds of pig iron containing about 1.5 to 2 per cent. of silicon is melted and rabbled about the bottom, washing the whole space. This iron gradually oxidizes, unites with the slag, sand, and burned iron in the bottom, loosens it, and forms a copious slag. When the whole is tapped out, very little iron is left, and that is of such a poor quality that it should only be fed cautiously, a little at a time, into the pot mixture. It is a good plan also to add a little fluorspar to this mixture to thin it down while in the furnace.

MALLEABLE-IRON PRODUCTION.

MELTING PROCESSES AND EQUIPMENT.

29. Classification of Melting Processes. — In American practice the iron for malleable castings is melted almost entirely in the cupola, the coal, or air, furnace, or the open-hearth furnace. As the melting process in each of these is somewhat different, this subject is divided under these three headings, and the process for each explained.

30. The Cupola Process.—Malleable iron melted in a cupola has the disadvantage of an extremely close structure in the hard casting; this causes trouble in annealing. In fact, an annealing oven charged with cupola iron always

requires a temperature of from 200° to 300° F. above that necessary to anneal furnace iron in order to effect the change of carbon. The castings are, moreover, not as strong as those made of furnace iron, and hence cupola iron is used only for the lightest work where the shape is more important than the strength. The cost is, however, about ½ cent less per pound than the same castings made of furnace iron, and for this reason saddlery, hardware, pipe fittings, bicycle parts, wagon castings, etc. are all made of cupola iron. Where strength is essential, as in the case of car couplers, motor gears, etc., and steel castings are too expensive, furnace malleable is always used.

The process of melting a malleable mixture in a cupola is the same as that for melting gray iron, which is fully described in *Cupola Practice*. As has already been stated, the only difference between the mixture used in cupola practice in gray iron and malleable lies in the amount of coke used. In the best average practice in malleable-iron work 4 pounds of iron is charged to 1 pound of coke. A larger proportion of coke is used than in gray iron in order to insure a sufficiently high temperature to make the iron run freely. The iron should be so hot when poured that it squirts out of the vents in the molds.

In making the mixture and preparing the charge for the cupola, it is important that the pig iron be broken up into small pieces; as in melting, the thin sprues melt first and go to the bottom, while the more slowly melting pig iron comes down afterwards. If the cupola is tapped out into hand ladles instead of a bull ladle, and this is usually the case, in order that the iron may be kept as hot as possible, there is every likelihood of the low-silicon metal getting into the molds that are poured first, and the high-silicon iron into the last. Both sets of castings are therefore liable to be bad, not only in their composition, which causes trouble in the annealing process, but the castings made first are made entirely of scrap and the last entirely of pig iron. The scrap castings are liable to crack and warp, and the pig-iron castings are spongy and weak.

31. Coal-Furnace, or Air-Furnace, Process.—The **coal-furnace, or air-furnace, process** makes better malleable castings than the cupola process. It takes longer to prepare the heat, but allows it to be poured more quickly, thus giving the molders more time for actual molding. It was formerly the aim of every malleable-foundry owner to put in coal furnaces, just as at the present time it is the aim to use the open-hearth furnace. The disadvantage of all hearth or furnace processes as against the cupola lies in the greater lack of flexibility, a furnace not being economical when not fully charged. The expense of running the cupola is less, but this is offset by the better grade of castings produced by the furnace processes. A breakdown of the cupola, also, is more serious, and the delay longer. The first cost of the coal furnace is, however, greater than the cupola, and the open-hearth furnace is still more expensive.

The coal-furnace process is carried out in several ways. In the simplest of these the ordinary reverberatory furnace, which is illustrated in Fig. 1, is used. Although it has been almost entirely superseded by other forms, it is the least

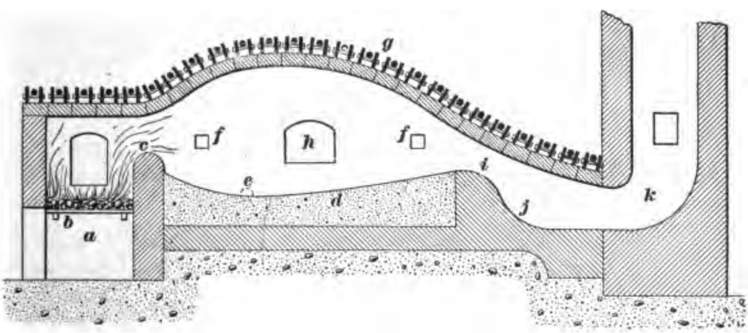


FIG. 1.

complicated form of furnace and is still used in some malleable foundries. As the air is supplied by natural draft, the melting is necessarily slow. The iron is, however, for this reason not subjected to the serious oxidation of a blast, and better castings are therefore produced. Excessive oxidation causes pinholes in the surface of the castings, and

these are avoided by this process. The better grade of fittings, skates, pistols, and all articles requiring subsequent polishing seem to give least trouble when melted in this slow, although expensive, way.

32. Construction of Coal, or Air, Furnace.—In the furnace shown in Fig. 1, *a* is the ash-pit, at the front of which are located the ash-pit doors used for cleaning the fires. The door opening should extend far enough above the grate-bar rests to permit the grate bars to be drawn out when the fire is dumped. The grate is shown at *b*, with the firing door just above; *c* is the bridge wall over which the flames travel, striking the roof, and reflecting heat downwards on the charge, which is piled on the sand bottom *d*. When melted, the charge is tapped out at *e*; *f*, *f* are poke holes through which the charge is rabbled and, if desired, poled with green hickory poles; *h* is the skimming and charging door, the bottom of which is on a level

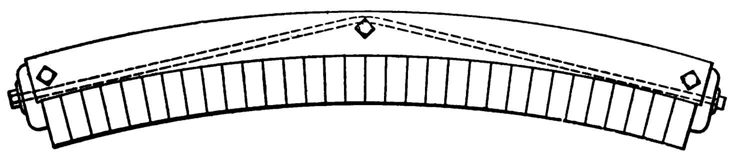


FIG. 2.

with the top of the bath of melted iron. The roof *g* consists of a series of brick arches, about 9 inches thick and about 13 inches wide, constructed as shown in Fig. 2. These arches, commonly called **bungs,** can be repaired easily when burned out or broken, and when lifted off leave the whole furnace bottom exposed for remaking or repairs. The sides of the furnace are usually formed of cast-iron plates, to which are attached the charging and skimming doors and the firing apron; the plates are properly held together with buckstaves and tie-rods, and are lined with firebrick, which must be of the first quality.

33. There should be no sharp corners in the furnace interior, as the brick at the corners would soon burn off,

Expensive repairs at the base of the stack, for instance, can easily be avoided by rounding the corners of the flue, as shown at *i*, *j*, and *k*, Fig. 1, instead of making them sharp, as shown by the full lines in Fig. 3. The dotted lines in Fig. 3 show how, when the corners are left square, the flames cut out the brick after a few weeks' run.

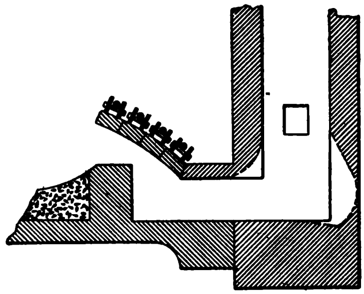


FIG. 3.

34. The other, and more generally used, forms of the reverberatory, or coal, or straight-draft, furnace, as it is sometimes called, differ from the simple form just illustrated only in the addition of an air blast to hasten the melting process. Two modifications of this more modern type are in use. In the first the blast is introduced into the ash-pit, as shown at *a*,

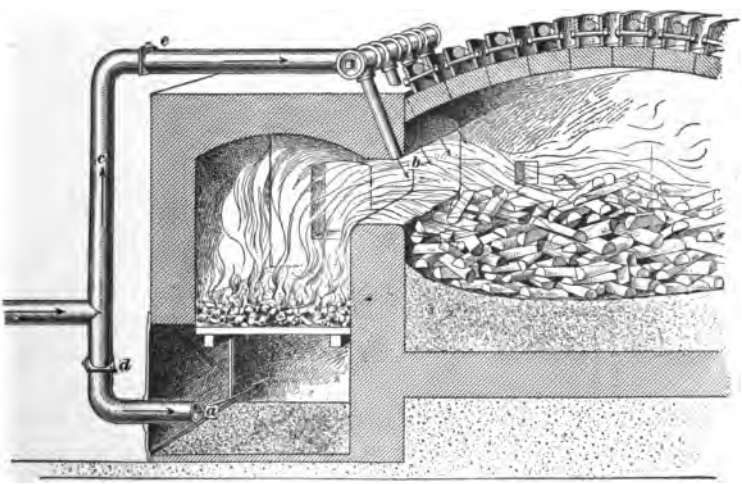


FIG. 4.

Fig. 4; while in the second modification, an additional air blast is introduced over the bridge wall, as shown at *b*; the

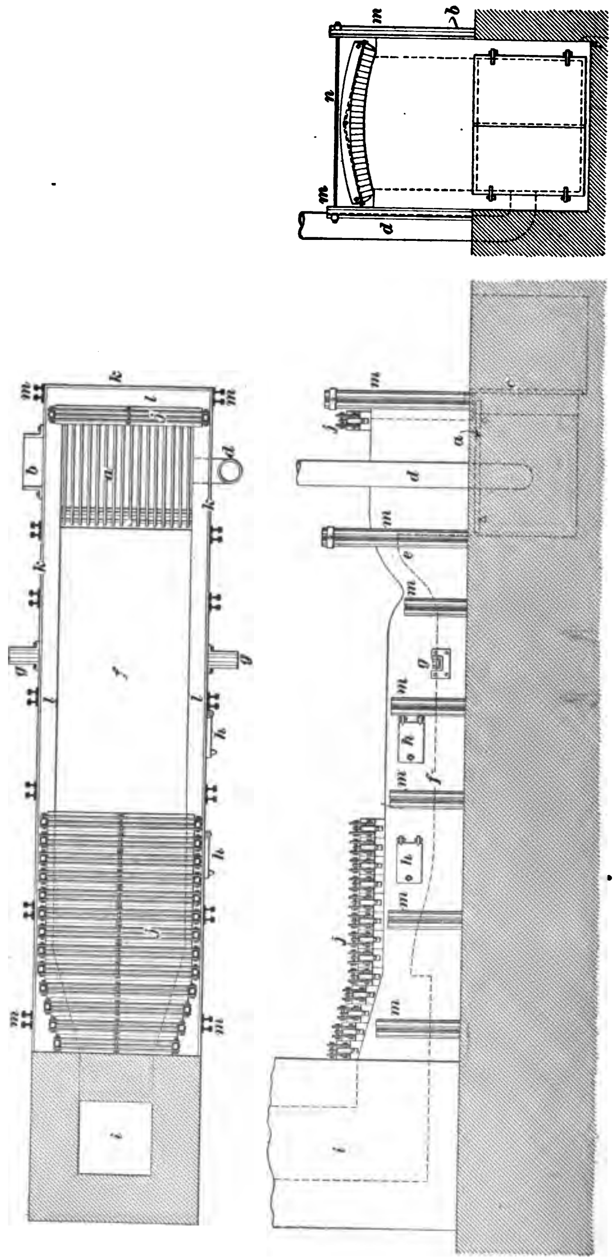


FIG. 5.

object of the second blast being to force the flame down upon the iron and complete the combustion. The fire obtained by means of this arrangement is very hot, and the time required to do the melting is very much shortened thereby, it being possible by this method to melt a charge of about 7 tons in about 4 hours, while with the natural-draft system it might take nearer 7. It is at the present time used more extensively than any other method, although the very high temperature of the flame is rather hard on the iron.

In Fig. 4 the bungs do not extend over the grate, this part being arched over with brickwork. Practice differs somewhat in this respect, some malleable-iron founders preferring this construction, while others prefer to have the bungs extend clear to the front of the furnace, as shown in Fig. 1. The blast pipe *c*, Fig. 4, is usually made of galvanized iron, the bends being made of a radius equal to the diameter of the pipe. The blast gates *d* and *e* are simply dampers inserted in the pipe. The blast should be brought in at the side of the furnace in order to allow the ash-pit doors to be placed at the front. This will enable the fires to be drawn more easily. In Fig. 4, the blast pipe is shown at *a* instead of on the side of the furnace in order to simplify the illustration.

35. Fig. 5 shows the type of furnace ordinarily used in a malleable-iron foundry; *a* is the grate, *b* the fire-door and apron; *c* the ash-pit doors, *d* the blast pipe, *e* the bridge wall, *f* the hearth, *g*, *g* the tapping spouts, *h*, *h* the charging doors, *i* the chimney flue, *j*, *j* the bungs, *k* the cast-iron plates forming the outside of the furnace, *l* the brick lining, *m* the buckstaves, and *n* the tie-rods. When more than one heat is taken from a furnace in a day, one bung at the middle may be made of double width to facilitate the charging when the furnace is hot.

36. The most important part of a furnace is the bottom, or the sand hearth *d*, Fig. 1. Owing to the higher temperature to which it is subjected, the bottom of the open-hearth

furnace requires much more attention than that of the coal furnace. If the bottom is put in rightly when the furnace is first built, it is generally necessary to repair it only after every second or third heat. The material used for the bottom is fire-sand, which is a very sharp sand containing nearly 100 per cent. of pure silica, although it may contain up to 1 per cent. of lime, iron, and clay. It is often a ground sandstone. When the intense heat has played on the bottom for a short time, a crust forms on the surface; this prevents the sand from rising up and floating on the bath of melted iron. If the sand were permitted to float, the iron would speedily cut its way through the bottom into the furnace pit. When this begins, and in fact in all other emergencies, the best available method must be used to stop the flow of iron. Each case requires individual treatment, and no method that will be applicable generally can be described. The necessity of each case, however, requires means to stop the flow as quickly as possible, either by the application of molding sand or even a stream of water, if it can be applied without disastrous consequences.

37. While the bottom of a furnace is the most important part, the roof, usually called the **crown,** must also be looked after carefully. A small pneumatic crane installed next to the furnace, to lift the bungs or individual sections of the crown, swing them over the furnace, and run them out into position, will be found of very great service. Another arrangement for handling the bungs is to support, lengthwise over the furnace, an **I** beam equipped with a hand-operated chain hoist that travels upon it; this is the older method, and it is gradually being displaced by more modern and more rapid methods. The bungs when placed into position are carefully mudded up so that no heat may escape or cold air be drawn in. This is done with fireclay mixed with sand, wetted down, and worked into a plastic mass.

38. The preparation of the filling in which the tap hole is formed, commonly called the **breast,** requires great care; for if it should give away while tapping the whole heat would

run on the floor, and if the roof of the building should be made of wood, it would probably burn down the whole foundry. The best material for making the breast is fire-sand that has been mixed with a little fireclay to bind it, and enough coke dust to allow it to be easily broken out. A common bod stick, similar to that used with a cupola, is used to close the tap hole. Graphite sleeves and stoppers for the tap hole, shown in Fig. 6, are now on the market,

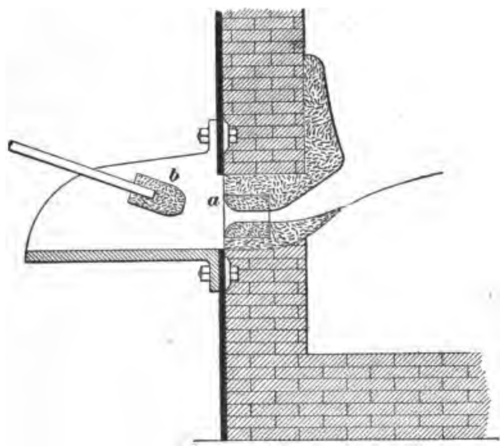


FIG. 6.

the sleeve *a* being built into the breast, and the stopper *b* mounted on a rod, as shown. The stopper is held against the spout while the stream is running and serves to check and, if necessary, to stop the flow. Where more than one heat is taken in a day, the breast is made substantial enough to last for the day's work. Great care must be taken in tapping after the first time, as iron that has become chilled may have lodged on the inside, and some heavy driving may be required to loosen it and crowd it inwards. This often so injures the breast that the heat runs out and is lost. The making of an extra breast is an expensive operation and requires considerable time; it is therefore naturally avoided whenever possible.

When the sleeve and stopper are not used in preparing the breast and running out the heat, the tapping hole is prepared exactly as in cupola practice. Several bod sticks are

FIG. 7.

kept on hand; these are usually made of iron of the type shown in Fig. 7.

39. The **spout** of a malleable furnace is longer than that used on a cupola; it is placed about 2 feet 6 inches above the floor level. Large furnaces may have two spouts, one on each side, the bottom being shaped as shown in Fig. 8. This is done to get out a large heat in as short a time as possible. The construction of the coal furnace and its usual position in the foundry allow a spout to be provided at each side.

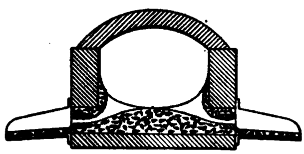


FIG. 8.

40. Charging the Coal Furnace.—In charging upon a cold bottom, the bungs of the furnace are usually taken off in order to repair the bottom if necessary, and make room for charging. If the bottom is newly made, old boards are laid on the sand to prevent the iron from making holes before the surface of the sand has hardened. The scrap or sprues from former heats, including scrap castings, is put in first. This is either shoveled in from a pile on the floor or brought from the scouring room in boxes, which are taken up by two or four men and emptied into the furnace. The scrap is then leveled and pig iron thrown in. It is a good practice to arrange the pig iron in regular piles perpendicular to the longitudinal axis of the furnace, piling it up like cord wood, beginning at the bridge wall and ending at the throat or entrance to the stack. The object of this piling is to facilitate the melting operations. The first to melt is the scrap, because it is comparatively thin and has a low melting point,

being white iron. In the meantime the stack of pig iron, which is directly in the current of the flame, is getting ready to melt down. The melter must then take his bar and throw down the end pigs into the melted bath, where they are soon assimilated. With a nice orderly pile this is comparatively easy, but with a pile of pigs thrown every way, it is very hard, and one must wait until the whole sinks down into a semifluid mass, which with much rabbling will gradually yield and mix into a homogeneous body of melted iron, but a valuable half hour will have been lost.

If more than one heat is taken in a continuous run, the charging is usually done by removing the charging bung, and charging the sprue and pig iron through the opening thus made. A portion of the iron may also in this case be charged through the skimming door, using for this purpose a short peel, which is described later on.

It takes from $\frac{3}{4}$ hour to $1\frac{1}{4}$ hours to charge a 10-ton heat. When steel is added to the mixture, it should be introduced after the metal has just melted and is covered with slag. Malleable scrap should be charged on top of the hard scrap and just under the pig iron. The limited gray-iron scrap accumulated by the malleable foundry can also be fed in a little at a time without injury to the resulting metal.

41. Melting and Refining.—When the temperature of the bath becomes high enough to cause oxidation in the bath itself, a refining process takes place. Considerable oxidation has probably been going on during the melting down of the pile of pig iron, as the scintillation noticeable as the flame sweeps over the pile indicates a combination of iron with oxygen. This results in a loss of silicon before the bath is uniformly fluid. As the bath is heated up, it becomes more fluid and the slag begins to separate and float on top, forming an effective protection for the iron while the heating is continued. When the bath is hot enough to show distinct signs of boiling, a reaction is going on within, the oxygen present uniting with the silicon and manganese and entering the slag as oxides of silicon or manganese. It is

now time to hasten this reaction and utilize the affinity of silicon for oxygen to partially burn out the silicon. This gives an interior heat that raises the temperature of the metal quicker than any firing will do. The bath is therefore skimmed, by means of a special skimming tool, shown in Fig. 9 (*a*), which is well daubed with clay wash and dried.

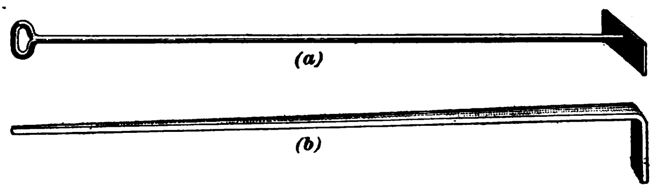


FIG. 9.

Another form of skimming tool, shown in Fig. 9 (*b*), may be made from a piece of $\frac{5}{8}'' \times 3''$ flat iron, drawn down to $1\frac{1}{8}$ inches on one end, and bent over at the flat end, as shown. This tool is easily made and lasts longer than the form shown in Fig. 9 (*a*).

The slag is skimmed off the bath and drawn out of a door in the side of the furnace provided for that purpose, after which it is wet down with water and removed. The bath is now clean and greedily absorbs the oxygen from the carbonic oxide and the free oxygen carried with the burning gases from the fuel. The combination of oxygen with the contents of the bath generates heat and the iron rapidly becomes highly overheated. It is now necessary to skim again, as the burning out of silicon makes slag, as does also the oxide of iron that is formed continually and combines with the sand of the bottom and sides. A test plug should also be taken at this stage. Any iron in the slag may be saved by rolling the latter in a cinder mill and washing it, which leaves the iron that has been skimmed off in the form of small shot free in the mill, the slag having been carried off.

42. A **test plug** is a test bar of iron about $1\frac{1}{2}$ inches in diameter and about 8 inches long, made in a mold formed by forcing a tapered piece of wood of about this size into a

box full of molding sand. A furnace dipping ladle shown in Fig. 10, which has previously been well daubed with clay wash and dried, is now taken and melted iron dipped from as low a point in the bath as the melter can reach by pushing the ladle downwards. This is poured into the hole

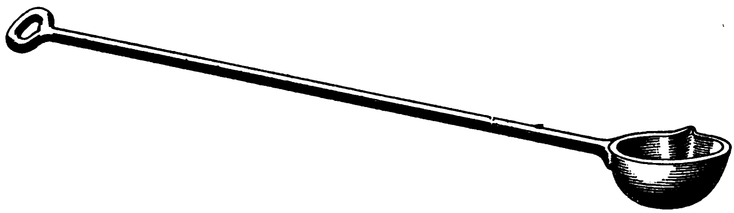


FIG. 10.

made in the molding sand and allowed to set. As soon as the iron will hold together it is drawn out with a pair of special tongs and cooled very slowly by dipping into a water tank, commonly called the *water bosh*, which is always kept near the furnace for the purpose of cooling the long and heavy poking bars.

In order to prevent too rapid cooling, it is advisable to plunge the bar into the water and withdraw it quickly, allow it to turn red, then dip it again, and repeat this operation until it is cool; this should occupy about 7 or 8 minutes. If it is cooled too rapidly, one is liable to be deceived regarding the condition of the iron in the furnace. Sudden cooling chills the iron and causes the fracture to appear white even when the iron is not of the right composition.

When the test bar has been cooled it is broken by striking it sharply against some iron corner and the fracture carefully observed. If it shows good radial crystals with little or no mottling in the center, the heat is ready to tap. If the plug is heavily mottled or even gray, the bath is either too cold or has too much silicon in it. It is then necessary to hold the heat anywhere from 10 minutes to 1 hour longer, the less the better for the iron. Tests are made from time to time until the desired fracture is obtained, after which the tapping is proceeded with at once.

If, on the other hand, the plug is perfectly white no time should be lost in tapping. If the heat has gone too far, the plug will show little pinholes along the edge or skin. If this is the case, it is advisable to add some ferrosilicon, say about 150 pounds or more, depending on the circumstances, broken up into small lumps. This should be stirred or rabbled in well, the heat held about 5 minutes, and then tapped.

43. Rabbling the Charge.—During the heat a good melter will rabble the iron at as frequent intervals as possible. The frequency with which this may be done is determined by the endurance of the melter, the work being exceedingly trying. By stirring frequently the bath is kept uniformly mixed and the chemical reaction promoted. The rabbling bars are often made of $1\frac{1}{2}$-inch round wrought iron,

FIG. 11.

about 15 feet long, and of the form shown in Fig. 11. Pieces are welded on as the end wears away. Bars of the above diameter are, however, rather heavy, and in some foundries a $1\frac{1}{8}$-inch bar, with the end bent over about 8 inches, is preferred. Steel bars are also used quite extensively in some foundries, as they are much cheaper than wrought iron, although they melt off more rapidly.

44. Firing the Coal Furnace.—It is very important that a continuous intense flame be maintained upon the charge of iron in the furnace. It is usually found economical, and the best results are obtained by wetting down the coal, which is then shoveled upon the firing apron. The bed of coal upon the grate bars should be leveled off, the coal pushed to the farther end of the firebox, and stirred or raked continuously by means of a small firing hook, which is similar in form to the slice bar used in firing a boiler. Continuous firing is necessary.

The apron on which the coal is shoveled consists of a cast-iron plate or trough bolted to the side of the furnace, and arranged to slope downwards toward the grate at an angle of about 30°.

A good grade of soft coal should be used, preferably rich in gas-making qualities and free from sulphur. With good firing and a well-proportioned blast, it should not require more than 50 pounds of coal for each 100 pounds of iron melted.

When more than one heat is taken from the furnace before cooling down and repairing the bottom, the fires must be cleaned between the heats, dumping all the ash and cinder into the ash-pit, and kindling a new fire upon the grate. If this is not done, the air spaces between the grate bars become so choked that it is impossible to obtain proper combustion, which results in a cold heat and bad iron.

MALLEABLE CASTING.

(PART 2.)

MALLEABLE-IRON PRODUCTION.

(Continued.)

OPEN-HEARTH MELTING PROCESS.

1. General Construction and Operation of Open-Hearth Furnace.—The **open-hearth process,** also called the **Siemens-Martin Process,** takes its name from the style of furnace used, which is known as the open-hearth, or regenerative, furnace, and in modern practice invariably uses gas or oil as a fuel. This style of furnace is called regenerative, because a portion of the heat of the waste gases is returned to the furnace with the incoming air and gas. In this style of furnace the ingoing air and gas, when gas is used, is heated by the hot gases as they leave the furnace. This is accomplished by the arrangement illustrated in Fig. 1, which shows a section through an open-hearth furnace constructed for the use of gas. In this illustration *a* is the hearth; *b* the crown or roof; *c*, *c*, *c* the charging doors; *d*, *d'* air ports; *e*, *e'* gas ports; *f*, *f'* and *g*, *g'* chambers, commonly called *regenerative chambers*, filled with **checkerwork,** which consists of special checker brick, about $2\frac{1}{2}$ in. $\times$ $2\frac{1}{2}$ in. $\times$ 9 in. in size, laid up loosely in alternate layers about $1\frac{1}{2}$ inches apart; *h*, *h'* are air inlet flues; and *i*, *i'* gas inlet flues. The flues *h*, *h'*

and *i*, *i'* are connected with pipes and valves that are so arranged that the incoming air and gas may be made to enter either side of the furnace at the will of the operator, while the burned gases go out at the other side. When the air and gas enter at *d* and *e*, the burned gases go out at *d'* and *e'*, and in circulating through the checkerwork in the chambers *f'* and *g'* heat the brick to a high temperature. If the direction of the gases through the furnace is reversed,

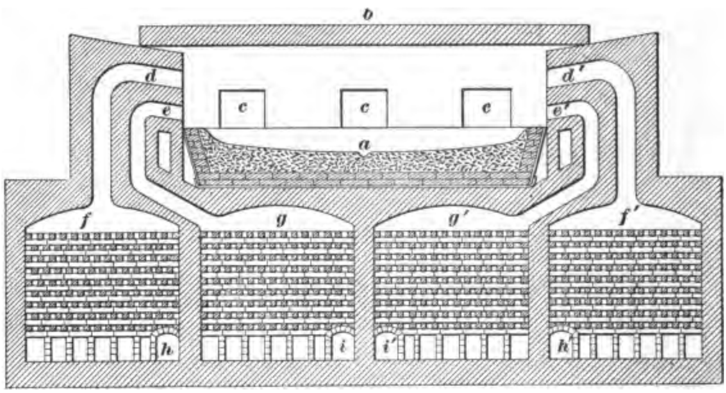


FIG. 1.

the cold air and gas will pass in through the chambers *f'* and *g'* and will take up the heat previously given to the brick, thus entering the furnace at a high temperature; the burned gases now pass out through the chambers *f* and *g* and heat the checkerwork in them. By reversing the direction of the gases at suitable periods, they will always enter the furnace in a highly heated condition, thus creating a flame of a very high temperature and saving a large amount of heat that would otherwise have passed up the chimney and been lost.

2. The arrangement of the gas and air piping outside of the furnace is shown in Fig. 2. The ends *h*, *h'* and *i*, *i'* connect with the flues marked with these letters in Fig. 1. At *j* and *j'* are two valves, by means of which the ingoing gases may be made to enter either side of the furnace, and

the burned gases made to go out at the other side, through the valves and the flue *k* to the chimney *l*; a plate damper is

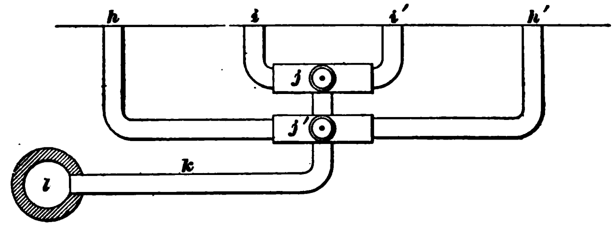


FIG. 2.

placed in the chimney flue *k* to regulate the draft. The valves *j*, *j′*, commonly called *Siemens valves*, are constructed as shown in Fig. 3, in which *m* is a disk valve, which is situated in a suitable chamber above the casting *q*, through which the air or gas enters; *n* is a butterfly valve; *o*, *o′* are openings that connect with the pipes leading to the furnace; *p* an opening that connects with the flue leading to the chimney; and *q* a casing enclosing the valve *n*.

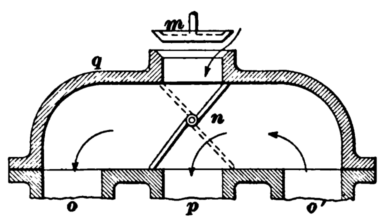


FIG. 3.

Suppose that the valve shown is connected at *j′*, Fig. 2, so that the opening *o* connects with *h*, and *o′* with *h′*. When the valve *n* is in the position shown, the air enters the valve *m*, passes through the opening *o*, through the flue *h*, Fig. 2, the chamber *f*, and flue *d*, Fig. 1, to the furnace. The gas enters through a similar valve, passes through the flue *i*, the chamber *g*, and flue *e* to the furnace. The hot air and hot gas meet and combustion takes place as they emerge from flues *d* and *e*. The burned gases divide as they leave the furnace and pass out through the flues *d′* and *e′*. The part that goes out through *d′* passes through the chamber *f′*, the flue *h′*, into the valve *j′* at *o′*, Fig. 3, and out through the opening *p* to the chimney, and the part that goes out through *e′* takes a similar course through the valve *j*,

into the chimney. It will be seen that when the butterfly valves *n*, Fig. 3, are turned to the position shown by the dotted lines, the air and gas pass through the valves *m*, through the openings *o'* into the furnace, and the burned gases enter the valves at *o* and pass out of the openings *p* to the chimney. The direction of the air through the furnace is thus reversed.

3. The burning gases give up most of their heat in the melting chamber. They are, however, still very hot, about 2,000° F., as they pass into the regenerative chambers. The cold brick checkerwork absorbs a large part of this heat, leaving the temperature about 800° F. when the gases leave the chambers. The brick gradually becomes hotter and the gases going up the stack also become hotter, as they cannot give up as much heat to the hot as to the cold brick. Hence, in about 20 minutes, it is no longer economical to let the gases flow in the same direction and the butterflies of the Siemens valves are reversed. The cold gas and air have been given some 1,200° F. before they reached the furnace, consequently the temperature created by the combustion is exceedingly high. While the cold air and gas are being heated on the right-hand checkers, they are cooling the brick in them, so that in about 20 minutes the direction of the gases should be reversed, or the one checker-chamber will become too cold and the other too hot.

By this process a large part of the heat value of the gas fuel is utilized, and a 10-ton heat can be melted and ready to take out in 2½ hours after charging. Cases have been known in which it took only 1 hour and 50 minutes, and with a well-constructed furnace, the ports new, the checkerwork clean, and the furnace in charge of a good melter, there is no reason why this should not be done without damaging the furnace.

This process has now been adopted in many of our most progressive malleable-iron works. Its full economy, however, will not be obtained until melting is done day and night, for the furnace must be kept hot all the time and the

cost of heating it at night brings no direct return. It can be used to the best advantage only where malleable castings are produced on a large scale and modern appliances are used in handling the metal.

In one malleable-iron foundry in operation at the present time there are several 18-ton furnaces giving good results. The metal is tapped into 6-ton ladles, and carried off with a 15-ton electric traveling crane. Three furnaces in operation at one time are able to furnish 100 tons of malleable castings for a day's run of three heats each.

Three forms, or adaptations, of the open-hearth furnace are in use. The simplest form, which has already been described and illustrated, is usually built of 10-ton or 12-ton capacity; the iron is tapped from this furnace into hand ladles in the usual way. Next comes a larger furnace of 15-ton or 20-ton capacity, built for melting steel if desired, which has three spouts for tapping into ladles handled by the traveling crane; this is probably the most successful, under suitable conditions, of the furnaces in use. Finally comes the tilting furnace, which has been used in steel manufacture and is at present being introduced in malleable-iron works. It is predicted by some engineers that it will prove successful, but up to the time of writing it has not been fully tried. The first cost of this furnace is about twice as great, and the cost of maintenance about four times as great as that of the ordinary type of open-hearth furnace.

4. The design of the air and gas passages, together with the ports, must be such that the crown of the furnace is as much protected from the cutting effect of the intensely hot flame as possible. While it is essential that the brick should be almost at the point of melting, this extreme temperature should not extend inwards over an inch at most. The best practice, therefore, allows the body of the furnace to become dangerously hot for a short time only; the heat is checked before any actual damage is done. The brick that stands high temperatures best is made of silica, and in all open-hearth furnaces built for malleable-iron work the

material above hearth level, in fact above the checker brick, should be of the best grade of silica brick. As this brick expands when heated, due allowance must be made for it in the arrangement of the buckstaves, or structural-iron supports, now customary.

In order to prevent injury to a new furnace, the melter must heat it very slowly, so as to thoroughly dry it out. He should first use wood fires or a small jet of natural gas, if it is available; in a week's time the heat can be increased and in 2 weeks' time the gas turned on, first very gently and then more and more until full heat is reached. In the meantime the melter should watch closely the structural ironwork and loosen or tighten tie-rods here and there as necessary. When ordinary firebrick is used, it is necessary to tighten the tie-rods, as it contracts when it is heated; the arches are thus prevented from cracking and the brickwork comes up to the required temperature with the least amount of damage.

5. Making the Bottom.—The hearth, as it is left by the furnace builder, consists of a steel pan with sloping sides, carefully riveted together, perforated for the spout, and

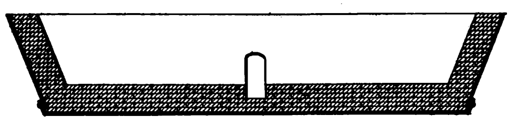


FIG. 4.

lined with silica brick, as shown in section in Fig. 4. When the furnace is heated to the proper point, the operation of making the bottom can be commenced. The melter throws about 2 inches of fire-sand and clean cupola slag, mixed in the proportion of about 20 parts of sand to 1 of slag, all over the bottom. The slag helps to cement the particles of sand together. He then increases the heat for a few hours and thoroughly bakes and consolidates the sand. He repeats this operation several times until he has a good base to work

upon, when he finishes the bottom, using the fire-sand without the slag. The spoon shown in Fig. 5, the end *a* of which consists of a shallow-dished plate, is now taken and the convex side used to smooth off the sand thrown on the bottom

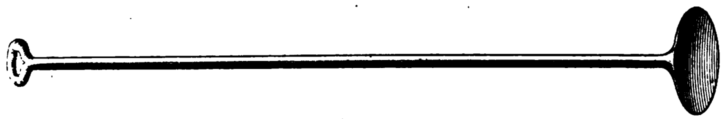
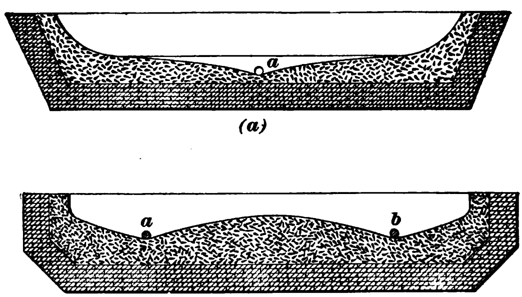


FIG. 5.

and against the sides while being burned on. When there are small patches to be put on, the sand is introduced with this spoon. Larger quantities are put on with a shovel; to do this properly, however, requires considerable skill in the use of the shovel. The work must be done very quickly, as the cold air that enters the furnace when the door is open chills it. In order to do this work in the shortest possible time, therefore, the helper throws the sand on the spoon as the melter draws it back, and in order to prevent any more chilling than is necessary, the door is raised only far enough to do the work properly. When it is necessary simply to throw in the sand, the melter does it himself, the helper raising and lowering the door quickly at the required time.



(a)

(b)

FIG. 6.

By building up the bottom to the proper level a few inches at a time the formation of heat cracks is avoided. This is a very important matter. The old coal furnace, or air furnace,

method, in which the bottom was made all at once, was adopted at first in open-hearth practice, but with very unsatisfactory results, as the rapid drying frequently caused it to crack to such an extent that the iron worked under sections of the bottom, thus loosening them and causing them to float. This permitted the molten iron to run out, fill up the checker-work, and spoil the furnace.

Fig. 6 (*a*) shows the bottom of the open-hearth furnace, with the tap hole being shown at *a*, as it should appear when completed. Where two spouts are provided for simultaneous tapping, it is necessary to slope the bottom as shown in Fig. 6 (*b*), the tap holes being shown at *a* and *b*.

6. Cleaning and Repairing the Bottom.—When the heat has been tapped and the slag run out, it is necessary to clean the bottom for the succeeding heat. The melter does this as best he can after the first or second heat, as in open-hearth practice the breast is not broken out until the close of the day's work, but after the last heat for the day has been taken and the breast is broken out, the hole is large enough for the melter to work through it with his scraping bars. He pushes the slag and dirt toward the tapping hole by introducing tools through the charging doors, and by working carefully through these openings is able to leave the bottom fairly clean. As, however, the bottom is liable to contain hollows in which small bodies of melted iron remain, which immediately begin to oxidize and burn up and thus cut a bad hole in the bottom, the melter must throw fire-sand on these spots to slag off the iron and get it out of the bottom. This often requires a few hours in the evening, and is best done by a good night man, who looks after all the furnaces that may be in operation, leaving them in good condition for charging in the early morning.

Care must be taken to keep the bottom in good condition in front of the ports. Small particles of iron oxide produced by the scintillation of the iron are carried forwards with the gases as they leave the furnace and are deposited at white heat upon the edge of the bottom immediately below the

ports. Iron oxide at this high temperature combines very readily with silica, forming an easily fusible silicate of iron, which usually runs down on the slag on top of the heat, but may, if not watched carefully, cut down between the ports and the bottom and open a way for iron to escape and injure the furnace.

"Run-outs" of iron usually occur along the slag line, on account of the fact that the greatest corrosive action takes place here. Moreover, the covering of slag, probably left there by a careless melter, may conceal a lump of burned iron, which by oxidizing and uniting with the sand surrounding it gradually eats into, and finally cuts through, the lining. The first intimation of the existence of this condition is a red-hot spot somewhere along the ironwork of the pan or the brickwork encasing it. No time must be lost in checking the trouble, otherwise the molten iron is liable to cut through and run out, resulting in the loss of the charge and often very serious injury to the furnace.

REPAIRING THE FURNACE.

7. Repairing the Ports and Surrounding Brickwork.—The parts of the open-hearth furnace first to require repair are usually the brickwork surrounding the air and gas ports. These parts are subjected to the highest temperature of the flame during combustion, as well as the corrosive action of the burned gases as they strike the ports upon leaving the furnace. In a few months' time, therefore, it must be expected that light repairs must be made. In designing a furnace, allowance should always be made for considerable burning back of the ports before the crown is endangered. Fig. 7 shows the construction of this portion of the furnace, the dotted lines showing the wear after a few hundred heats have been taken.

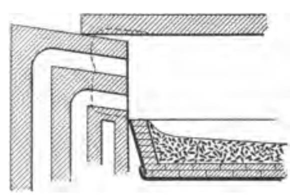


FIG. 7.

8. The **butterfly valve** should also be carefully watched, as it is liable to warp at the high temperature to which it is subjected. Inasmuch as the open-hearth process is essentially a gas process, it is necessary that the flues and valves through which the gas and air pass be as nearly gas-tight as the material of which they are constructed will permit. If the gas valve should leak, the gas thus escaping will mix with the waste products just emerging from the checker-work and pass up the chimney. The temperature existing in the flues promotes the ignition of this gas, and the valve and flues soon get red hot; finally the stack shows signs of undue heat and the melter investigates. By this time the valve may be cracked and ruined. By a careful daily inspection this trouble is detected at the beginning, and a little judicious chipping soon remedies it for the time being and allows the butterfly to seat itself properly. Both the gas and air valves should be inspected periodically, and if necessary, repaired in this way, as leakage of either hot air or gas into the stack causes a loss in efficiency. A number of valves have been introduced that aim to prevent the leakage by using a water seal. Some of these are very good, but they have the disadvantage of being rather expensive.

9. The **checkerwork** also should receive careful attention. It should neither be too open nor too closely laid. If the latter, it impedes the easy passage of the gases; if the former, they rush through without taking up or giving off heat. The space to be left is determined by the draft. With a strong chimney draft the spaces between the checker brick should be less than 1½ inches, but with an old choked-up furnace the spaces should be larger.

In the furnace, considerable iron is burned to iron oxide, which is carried down through and deposited in the checker chambers and flues. These deposits may become so great as to seriously interfere with the draft, so that it is advisable to occasionally open the furnace and clean it. This is exceedingly hot work, and should be undertaken before the trouble has gone too far. It may sometimes be necessary to remove

only one or two layers of the brick that form the checkerwork, as the oxide deposit usually coats these over, thus preventing the free flow of air through them, while the brick forming the lower portion of the checkerwork may be in as good condition as when it was put in.

Checkerwork for malleable purposes should preferably be made of firebrick of the first grade. Owing to the violent fluctuations in temperature to which they are subjected, a silica brick is less able to resist disintegration. Furthermore, the impinging of burned iron in the form of dust on a hot silica brick causes a glaze to be formed that partially destroys the heat-absorbing power possessed by a rough brick. In making repairs on a furnace it is important to lay the brick in such a way that when dipped into a thin mixture of clay and water, commonly called a clay puddle or grouting, placed in position, and pressed down, no surplus grouting runs down the courses below; if this is permitted, the natural roughness of the wall is destroyed and heat is not retained as well.

10. Repairing the Crown.—Patching the crown and work of like character can be done by lowering the temperature of the furnace just enough to allow the iron tools to hold their form while the work in hand is being done.

11. The Chimney.—The whole action of the furnace depends on the draft. This is generally furnished in a 15-ton open-hearth furnace by a steel chimney 80 feet high, 4 feet in diameter, lined with brick 4 inches thick, and provided with a plate damper at the base so that the draft can be easily regulated. A hole is placed in the side, through which lighted waste may be introduced in order to start the draft after the furnace has been shut down for some time. The current of air in such a chimney, when in full operation, should be sufficient to hold the water gauge at a pressure of .8 inch.

12. Charging the open-hearth furnace differs somewhat from coal-furnace, or air-furnace, practice. In the first

place, the furnace has probably been kept hot all night with a light flame, and about 2 hours before the time for charging the heat has been increased to as high a point as possible without injury to the furnace; the doors are raised and lowered quickly, as the charge goes in a little at a time. In coal-furnace practice the furnace is cold, or nearly so, and the whole top is removed to do the charging. The bottom of the open-hearth furnace must be in good condition.

The charging usually requires a gang of six men, two to pull up the doors, one of which is counterbalanced at one side of the furnace and the other two at the other side. The other four men shovel in the sprues and malleable scrap, the sprues being put in first. When the sprues and malleable scrap are all in, it is usually necessary to wait a few minutes to allow the charge of scrap to melt partially in order to make room for the pig iron. During this period of waiting the furnace also recovers a little of the temperature lost by the cold air coming in through the doors. A bar or roller *a*,

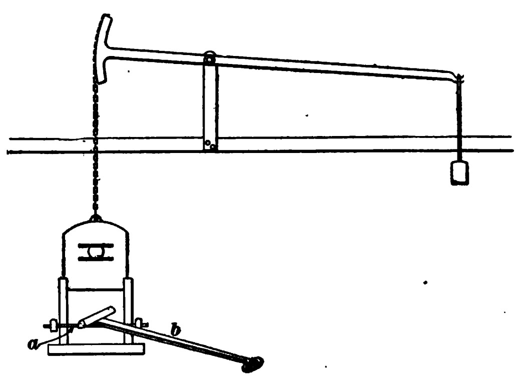


FIG. 8.

Fig. 8, is now placed in sockets, provided for the purpose, across one of the charging doors and the front end of a peel *b*, Fig. 9, is laid on it. Laborers then lay the pig iron, a piece at a time, on the peel, as shown in Fig. 8, and the helper raises the door while the melter moves the peel forwards and deposits the pig at the desired place.

Sometimes the sprues and small scrap is charged into the furnace by means of a charging box, which usually consists of a bar or handle similar to the charging peel, Fig. 9, but

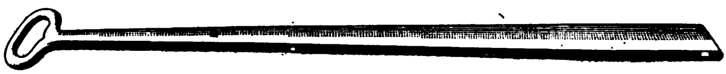


FIG. 9.

somewhat lighter. A bowl made of malleable cast iron 16 or 18 inches in diameter is riveted to the peel near the front end, the latter being allowed to project far enough to rest upon the charging bar or roll in front of the furnace door. The sprues and small scrap, which are usually brought to the charging platform in small foundry, or tote, boxes, are poured from these into the bowl and charged into the furnace in the same manner as the pig iron. This method is much easier on the men than shoveling the material into the furnace, as the heat, when the charging doors are raised, is so intense that it is extremely hard for them to throw the material in with short-handled shovels.

When enough has been charged on the part of the bottom commanded by one charging door, the second and then the third doors are used, thus making the best distribution possible for the purpose of melting the iron in the shortest time. It takes about 1 hour to charge a 12-ton heat, and as there are three reversals of the gas and air during this time, an alteration of the flame from one side to the other may be obtained when a fresh pile of pig iron has been piled up in front of the ports, thus causing it to be heated very rapidly.

13. Charging machines of the form used in steel plants have been suggested for malleable-iron foundries, but their first cost and the room required to operate them are so great that it is generally admitted that they are economical only when the furnaces are large, of at least 20 tons capacity, and there are about eight of them in line. The requirements of steel manufacture, so far as charging is concerned, differ from those of malleable-iron foundries. In steel manufacture, it is desirable to place the charge into the furnace

as quickly as possible and to subject it to the cutting flame, which may oxidize it as much as desired, while in malleable-iron practice the charging must be done carefully and with some time between the charging of the lighter materials and the pig iron, in order that the latter may be immersed in a bath of molten iron covered by a coating of slag as speedily as possible so as to prevent oxidation. If the iron could be melted without any oxidation, it would be most desirable, but this can be done only with the crucible process, which is not used in American practice.

14. Arrangement of Tapping Spouts.—In coal-furnace, or air-furnace, practice it has been customary to tap the metal from one spout. In this case the bottom of the spout must not be higher than the lowest part of the bath, and the metal lying at the bottom is therefore drawn off first. As the top of the bath always has the highest temperature, since it is in direct contact with the hot gases, the coldest iron is drawn off first, and by the time the top reaches the spout it is apt to have been subjected to the action of the burning gases so long as to be spoiled, and much of it may occasionally have to be thrown away. In order to avoid this danger, the furnace is often equipped with two spouts, on one or both sides, one being set higher than the other, so as to permit the upper half to be drawn off first through the upper spout, then the lower half through the lower spout. The upper surface is thus removed before it has been subjected to the hot gases too long, while the lower, or colder, part of the bath is heated to the required temperature before it is drawn off.

In the open-hearth furnace of ordinary size, either one or two spouts arranged as indicated above may be used, depending on the size of the furnace, while the largest furnaces may be provided with three spouts so arranged that they divide the charge into three approximately equal parts.

When only one spout is used there is also danger that the test plug, the iron for which is dipped from the top of the bath, may not indicate the true condition of the iron at the

bottom, and the castings poured from the iron first drawn may be bad. Unfortunately, this fact is usually not detected until the castings have been annealed, and all the work done on them, in addition to the first cost of the casting, is lost. When the furnace is provided with two or three spouts this danger is almost entirely avoided.

15. The form of the bottom of the furnace and the arrangement of the spouts, when three are used, are shown

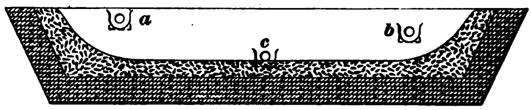


FIG. 10.

in Fig. 10, *a* being the highest spout, *b* the intermediate, and *c* the lowest, which should always be at the middle of the bottom.

While this arrangement of the spouts is used successfully with ordinary hand ladles, it can be used more advantageously in connection with a large ladle and a traveling crane. When the heat is ready and a crane is available, the upper spout is tapped into a 6-ton ladle suspended before it. A stream about 3 inches in diameter will fill the ladle with all the iron above the level of the upper tap hole in about 3 minutes. When the slag appears at this hole a clay plug is worked in, effectually stopping the flow of iron.

The ladle full of iron is carried to the part of the foundry where the iron is to be used, poured into hand ladles, from which it is poured into the molds by the molders. When nearly empty the large ladle is taken back; the small quantity of iron not used is probably quite cold, but is heated up again by the new charge tapped into the ladle. The second spout is now tapped and the operation of distributing and pouring repeated. This time all the iron is used for casting purposes. When the ladle is returned for the final tap, the clay closing the breast is carefully dug away from the outside and the breast pushed out from within. In about ½ minute the remainder of the heat is in the ladle, which overflows

with slag, leaving the surface in the form of a boiling, seething mass. It is skimmed off roughly and taken to the molding floor; the slag remaining on the surface is allowed to incrust a little, when a small hole is broken through, and the iron poured into hand ladles, and the molds poured, as indicated above.

In this manner a 15-ton heat is taken out in ½ hour, the iron is uniform in temperature, being protected by the slag, also practically uniform in composition until the entire charge is poured out of the large ladle. In this way the iron can be made hot enough so that at any stage of the casting it will shoot out of the vent holes in the lower ends of the small molds that have been set on an incline, which is good evidence that its temperature is suitable for malleable casting.

16. The **tilting open-hearth furnace,** which accomplishes the same purpose as the three-spout open-hearth furnace, by allowing the upper and hotter part of the bath of iron to be poured first, is now being introduced. It has, however, the disadvantage of a very high first cost and a large cost for maintenance. The first cost is further increased by the installation of hydraulic machinery to operate the tilting mechanism.

The furnace is stationary in all its details, except the hearth and crown. These revolve past the ports when pouring the iron from the spout, which is normally above the slag line. Fig. 11 shows a cross-section of the furnace in which *a* is the pan, *b* the bottom, *c* the charging door, *d* the tapping spout, *e* the gas and air ports, *f* a sector attached to the pan upon which the furnace is supported, *g*, *g* rollers upon which the furnace is tilted, *h* a hydraulic cylinder by means of which the furnace is tilted, *i* a checker chamber, and *j* the charging platform. By applying hydraulic pressure to the cylinder *h* the furnace is made to roll upon

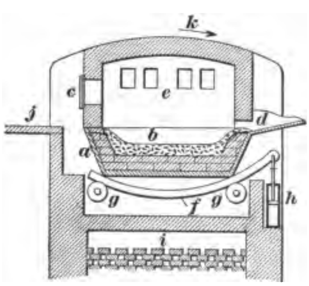


FIG. 11.

the rollers *g*, *g* in the direction indicated by the arrow *k* until the spout *d* is lowered sufficiently to permit as much melted iron to run out as may be desired.

The ports of this type of furnace are very difficult to keep in repair, and an extra set already built up and enclosed by structural steel is usually kept on hand, so that those in use can readily be renewed if they should give way.

While these furnaces are to be recommended to new concerns with a large amount of money to invest, it is generally thought advisable for works already equipped with other types not to change to this form until its practical advantages have been more fully demonstrated.

17. Fuel for Open-Hearth Furnaces.—The **fuel** used in open-hearth furnaces may be natural gas, oil, or producer gas made from coal. The latter may be used directly in the furnace by allowing it to run through suitable pipes in the side walls or the interior brickwork of the furnace, or it may be sprayed into the furnace with steam or with compressed air. Where air is used, it may be taken either from a fan, positive blower, or an air compressor. The construction of the open-hearth furnace depends considerably on what kind of fuel is used.

18. Natural gas, which is extensively used in malleable works for melting and annealing, is an exceedingly rich fuel gas. It has about five times the heating value of ordinary coal gas and is equal to oil in fuel value. Experience has shown that in burning it for melting iron in the open-hearth furnace, the gas regenerative chambers can be dispensed with, in which case large regenerative chambers for air are used; the natural gas enters the air ports on the ends of the furnace, as shown at *a* and *b*, Fig. 12. These pipes are usually built in and protected with a firebrick covering in order to prevent undue waste of the iron of which they are composed. In this style of furnace only one Siemens valve is required, and the equipment may therefore be greatly simplified.

While in open-hearth furnaces in which only natural gas is used the air is generally passed through the regenerative chambers, it is not advisable to build them with only one set of chambers. The supply of natural gas is very uncertain, especially in winter, when it is frequently shut off from

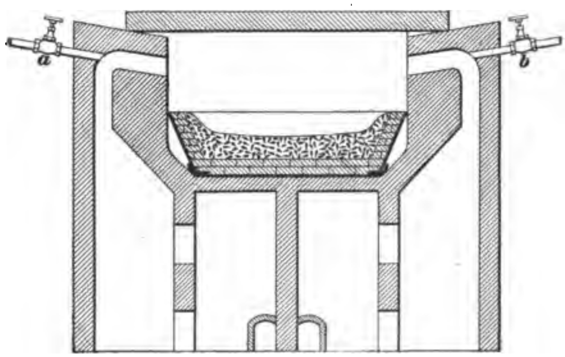


FIG. 12.

mills in order to supply the better-paying private customers. The regular open-hearth furnace with both sets of chambers should therefore be installed and the air allowed to go through both valves, while the gas is brought in as shown in Fig. 12.

Malleable cast iron has been made very successfully by passing the natural gas through regenerative chambers; this, however, produces an excessively hot flame, and the intense heat causes the metal to be oxidized too much as it melts down. When natural gas is used regeneratively a little steam should be admitted into the furnace over the gas valve, as this will effectually prevent the deposition of carbon at the entrance to the pipes and prevent their choking up.

19. Oil is now generally burned by spraying it into the furnace. The general arrangement of a burner suitable for this purpose is shown in Fig. 13. Oil is forced in through the tube *a* under a pressure of about 35 pounds per square inch, and is sprayed through a small hole, less than $\frac{1}{16}$ inch

in diameter. The air enters through the pipe *b* and carries the fine spray of oil into the furnace, where it is ignited and burned. If the temperature of the air is approximately that of the furnace, the oil will readily be gasified. When compressed air or steam is used, the air pipe surrounding the oil nozzle is made much smaller than when the air is

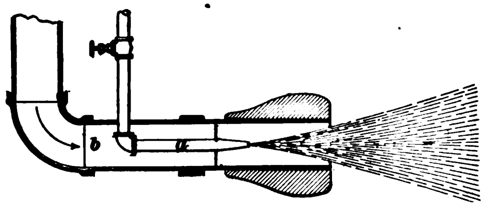


FIG. 13.

supplied by a blower. Opinions differ considerably regarding the most satisfactory air pressure to be used, some advocating a pressure of 1 pound produced by a positive blower, while others claim that the best results are obtained by using a pressure of about 40 pounds. The oil is sometimes introduced into the sides of the furnace, as illustrated in Fig. 14, the burners *a*, *b*, *c*, and *d* sloping downwards

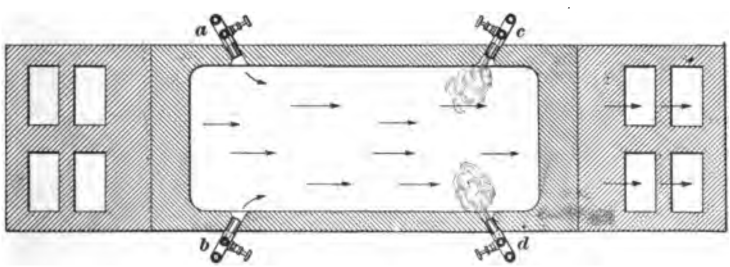


FIG. 14.

toward the hearth. In other cases the oil burners are located in the same position as the gas burners shown in Fig. 12. In this style of furnace it would also be possible to dispense with the second set of checker chambers, as in the case of the natural-gas furnace. If steam is available, there is an advantage in letting a little issue from the

burners that are not in use, as this tends to prevent the tips from being burned away.

In conveying the oil from the supply tank, which should be buried beneath the surface of the ground, a duplex self-governing pump should be used and a strainer placed before each burner, as otherwise the small hole in the end of the oil pipe is liable to become clogged so that no oil can pass through it. Oil can also be burned directly by simply letting a small stream flow down upon the melting iron. This method, while in a measure successful, is very hard on the furnace and is not to be recommended.

20. Producer gas is probably the most important gas with which the malleable-iron manufacturer has to deal. Modern producer gas is the product of a combined distillation and water-gas process. In the distillation process, coal is heated in a retort and gas is given off, leaving coke behind. In the water-gas process the temperature of coke is raised to incandescence and steam is introduced, cooling the coke, but making large quantities of carbonic oxide and hydrogen. For ordinary water gas, hard coal is used. Instead of raising the temperature of the coke and permitting the steam to blow upon it alternately, the steam is so introduced that it carries enough air with it to keep the temperature uniformly high enough to enable the gas to be formed continuously. The apparatus with which the gas is made is called a *producer*, and the gas is called *producer gas*.

21. Composition of Producer Gas.—Bituminous coal is generally used in making producer gas. The tarry products that are distilled off are allowed to go directly into the gas flues and are burned in the furnaces. A good producer gas should have the following composition:

Carbonic acid	4.5
Carbonic oxide	24.2
Hydrogen	12.6
Oxygen	.5
Nitrogen	58.2
	100.0

Carbonic acid is worthless as a fuel, and its presence above the 4.5 per cent. is a sign of carelessness somewhere. The presence of about that amount is, however, practically unavoidable.

Carbonic oxide is the constituent by means of which the greater part of the heat is produced. When burned with air it is converted into carbonic acid.

Hydrogen is a powerful heating agent. It produces a much more intense heat than carbonic oxide, but it is not very desirable for melting purposes. In burning, water is formed just at the ports of the furnace. Water when subjected to a very high temperature dissociates again into hydrogen and oxygen, the gases of which it is composed, abstracting the heat it gave out in burning. This process of associating and dissociating of hydrogen and oxygen may take place a number of times in the furnace until the last burning occurs at a point where the temperature is not high enough to produce dissociation. As this occurs in the checkerwork and not in the melting chamber, the effect is almost entirely lost. The direct value for melting of a gas rich in hydrogen is therefore much less than the total heat value would indicate. It is advisable, therefore, to keep the hydrogen as low as possible with a high percentage of carbonic oxide.

Oxygen is a very undesirable element in a gas, as it causes combustion in the flues, or even in the producer, thus burning a part of the gas before it reaches the furnace, and reducing its value as a fuel.

Nitrogen, of which the remainder of the gas is composed, does not burn and is valueless as a fuel. Unfortunately, its percentage cannot be reduced below 50 per cent., and more frequently it is 60 per cent.

22. The Gas Producer and Its Connections. Fig. 15 shows the cross-section of a producer in its simplest form. It consists of a shell of steel *a*, about 7 feet in diameter and 10 feet high, lined with 9-inch firebrick; a cover *b*, provided with the bell-and-hopper charging device *c*; a gas

outlet *d*; a grate *e*, upon which the coal falls through the charging device *c*; a set of poke holes *f*, *f*, through which the fire is broken up and kept open for the passage of steam and air; a steam siphon or blower *g*, through which air is taken in large quantities, and which operates at a steam pressure of about 45 pounds. The producer is set into a steel pan *h* filled with water, which forms a water seal that protects the lower part of the apparatus from leakage of air or gas, yet permits the ashes to be removed.

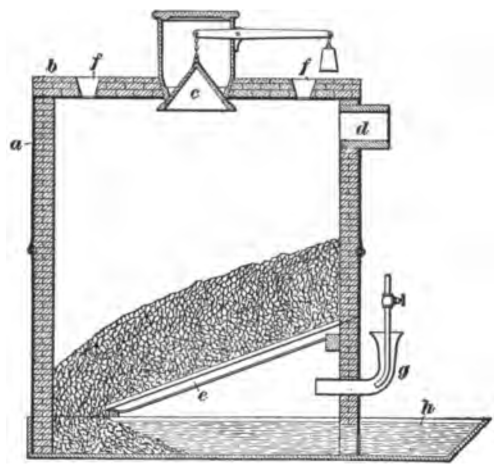


FIG. 15.

To start the producer, a wood fire is built in it, a load of coke is then added; when this is raised to incandescence the hopper *c* is filled with coal and the cover put on. The bell is now lowered and raised again, the coal dropping upon the bed of coke. In the meantime, steam is turned on and carefully regulated. Gas is generated immediately and forced out of the discharge pipe *d*. As soon as the soft coal strikes the incandescent coke, dense volumes of smoke are generated, which, however, should be used just as gas. The hopper is now filled, and the contents dropped upon the fire repeatedly until a good bed of red-hot coal about 2½ feet thick is distributed pretty evenly on the grate.

The amount of coal used will depend on the amount of gas required, and may vary from 300 to 600 pounds per hour for a producer 7 feet in diameter and 10 feet high. A producer 10 feet in diameter and 10 feet high will gasify from 1,000 to 1,200 pounds of coal per hour.

23. When a chemical laboratory is available the gas should be analyzed at least twice in 24 hours. Excessive amounts of the two injurious ingredients, oxygen and carbonic acid, are readily detected by a chemical analysis. As the air and steam strike the incandescent fuel on the grate two distinct reactions take place. There is first a formation of carbonic acid through the burning of the coal. This carbonic acid in passing upwards through the red-hot coal takes up extra carbon and becomes carbonic oxide, which is the valuable fuel constituent of the gas. If by analysis it should be found that there is an undue amount of carbonic acid in the gas, it is a sign of a thin or a cold fire, usually the former, the gasworker having permitted the bed of coal to burn down too far before replenishing it.

On the other hand, unless the fire is continually poked up, the clinkers broken and air channels through the coal destroyed, cold air is liable to come through the fuel and burn the gas before it leaves the producer. The quantity of oxygen in the gas will indicate whether or not this condition exists.

While the air drawn in causes the reactions described above, the steam is equally active. The air serves to keep the fuel in a state of incandescence, and the steam is continually decomposed into hydrogen and oxygen. The oxygen immediately combines with carbon and forms carbonic acid and carbonic oxide in turn. The hydrogen remains free and ascends through the coal fire into the gas flue uncombined. Usually the percentage of hydrogen varies from 10 to 13 per cent. The less hydrogen the better, provided the percentage of carbonic oxide is above 24 per cent. The gas burns with a rich yellow flame, is smoky, and has a tarry odor.

In a well-conducted gas plant the various chemical combinations are so complete that the ash as it comes out of the ash tanks is perfectly white and without a trace of coke cinders. It is wise, therefore, to inspect the ashes when they are removed, in order to see if the fullest measure of economy has been obtained. About 50,000 cubic feet of gas is made by this process from 1 ton of coal.

24. When gas leaves the producer it enters a breeching, shown in Fig. 16, which is connected with large overhead gas flues that may be 6 feet in diameter, through which it is conveyed to the furnaces. The breeching is connected to the producer at *a* and to the gas flue at *b*. A manhole is provided at *c* to clean out the ashes that may accumulate in the breeching. A safety damper *d*, which is blown open in case of an explosion, and a damper *e*, which may be closed when it is desired to cut one producer out of a series, are provided.

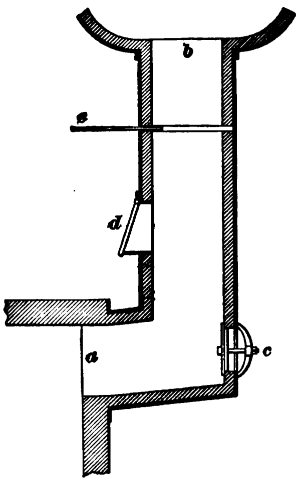


FIG. 16.

All the ironwork of the breechings and flues is lined with 4-inch firebrick of No. 2, or even less, refractory quality. The farther away from the producer, the cheaper the quality of brick may be, as the temperature is gradually lowered as the gas is conveyed away from the producer.

Good judgment must be exercised in selecting suitable qualities for the different purposes for which brick is used. No. 1 firebrick is made of the finest and most refractory quality of clay. The material is sorted with the greatest care and the unburned brick is subjected to pressure by special machinery previous to entering the kiln. This brick is suitable for temperatures above 2,400° F. No. 2 brick is made of the same material, probably not so carefully selected,

not subjected to pressure before burning, and is therefore not suitable for temperature much above 2,000° F. Flue brick is made of inferior clays, and may run from white to light red in color. The best grades will withstand temperatures up to 1,600° F., while the poorest grades will withstand only about 1,000° F.

25. All along the main flues, large safety manholes, consisting of cast-iron saddles and covers, made gas-tight

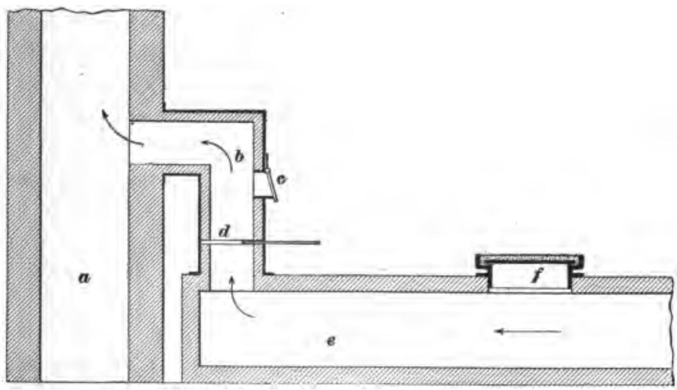


FIG. 17.

with a sand seal, are placed at intervals of about 100 feet. The end of the gas flue is connected with a stack and cut off from it with a damper, in order that the flues may be burned out about twice a week, so that the large amount of soot formed and deposited on the bottom, thus retarding the passage of the gas, may be removed. The connection with the chimney is illustrated in Fig. 17, the chimney being shown at *a*, the breeching connecting the flue with the chimney at *b*, a safety damper at *c*, a damper at *d*, the gas flue at *e*, and the safety manholes, showing the sand seal, at *f*. In burning out the flue, the damper *d*, Fig. 17, and the safety damper *d*, Fig. 16, are opened, and immediately the flame runs along the flue and into the chimney. In about 20 minutes all the soot will be burned out; the dampers are then replaced and gas made as usual. The dampers are

made to fit loosely in their guides, but the accumulation of tar upon them soon makes the joints gas-tight.

The connection with the open-hearth furnace is made through its gas valve. At this point a safety damper should be provided to prevent damage to the flues when an explosion occurs, as well as a regular plate damper to cut off the furnace when desired. The connection with the furnace should be at least 2 feet square; in fact all gas conduits should be very large, as the gas has only a fraction of an ounce pressure and a large volume is required in order to do the required heating in the furnace. The gas flues should be placed overhead whenever possible and a few bends should be inserted to take up the expansion and contraction due to the great variation of temperature to which it is subjected. It is more expensive to build an overhead steel shell lined with firebrick than to build an underground flue of flue brick and red brick only, but the underground flue will not stand the strain due to the variations of temperature, so that the overhead flue is more economical.

Producer gas, while presenting a different set of problems than natural gas, is equally as serviceable, makes good malleable iron, and when handled rightly is more reliable. In well-equipped plants the coal and the ashes are handled by conveyers and suitable dumping appliances, which leave only the work of the gas maker to be done by hand.

PREPARATION OF MOLDS FOR MALLEABLE CASTINGS.

26. The **molds for malleable-iron castings** are made in the same manner as green-sand molds for gray iron. In the matter of gating, however, there is some difference. Proper gating for malleable work is very important. Very often the failure of the iron to run may be ascribed as much to improper gating as to poor metal. Owing to the excessive shrinkage and the high temperature required to run thin sections, the gate must be made of sufficient size to prevent the iron from chilling before the farthest portions of

the mold are filled. The gate must also be carefully located at the most suitable place on the casting.

In gating small patterns, it is often necessary to provide a riser, commonly called a **shrinker** in malleable-foundry practice. The sudden cooling and shrinkage will cause spongy places unless some means is provided for feeding the metal to these parts. The shrinker may be of the same form as the pouring sprue and placed either on the gate, or it may be so located that it will feed the metal from a point outside of the casting. When the casting is too small to permit the use of these forms an enlargement may be made on the gate itself to provide a reservoir for feeding the parts where the shrinkage is liable to occur. These shrinkers are used in addition to the chills already mentioned. The shrinkage that is liable to occur in the center of a very heavy section is usually prevented by placing a large riser on the casting itself and breaking it off after the metal has set, but while it is still hot.

TAPPING AND POURING THE IRON.

27. Tapping the Iron.—In tapping out a heat the molders must form in lines and catch the metal in turn. It is essential that each man catch the iron promptly and that the line be unbroken. This will enable the melter to give the men a larger stream of metal, the heat is taken off more quickly, and the molders return to the floor or bench earlier than if the work were done in an irregular and unsystematic manner. To do this properly, it is necessary to have adequate space in front of the furnace, long bod sticks so that the men are not interfered with unnecessarily, a good foreman, molders who understand their work thoroughly, and every step of the process systematized as far as possible. When such a plan is in perfect operation the cost of the castings is reduced correspondingly.

It is very important that the heat be removed from the furnace as quickly as possible. If the pouring is prolonged unduly, the metal, which at the beginning of pouring was

hot and fluid, may become cool and sticky from the oxidizing process that goes on in the furnace, and which becomes even more rapid as the bath becomes thinner. For this reason it often occurs that the last portion of a heat, which at the beginning was in the right condition, must be thrown away or cast into pots.

28. Pouring the Iron.—In pouring the iron, it is necessary to place the lip of the ladle close to the pouring gate of the mold, and to pour the iron until the gate or the pouring basin, if one is provided, is just filled. By a very slight tilt of the ladle as much of the contents of the ladle as may be needed is shot into the mold. The castings for this class of work are exceedingly hard to run full, as the iron, in running through the damp sand of which the mold is composed, is liable to become chilled, and sometimes set, before the mold is completely filled. The iron for malleable castings must be very hot, and in order that it may fill the mold entirely before it is chilled, it must be poured as quickly as possible. It is claimed by some foundrymen that this can be accomplished better with the shallow form of ladle, shown in Fig. 18, as tilting the handle slightly will suddenly

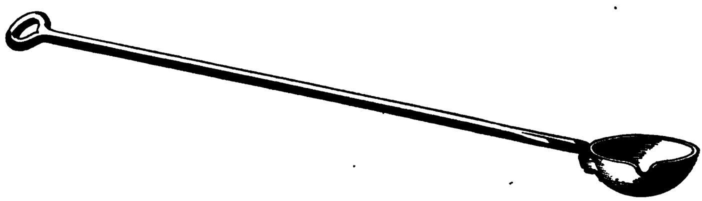


FIG. 18.

throw a larger body of metal into the mold. It is claimed by others, however, that the metal cools more rapidly in the shallow ladle, and that this cooling offsets the advantages claimed, while the metal can be poured as rapidly with the common deep ladle used in gray-iron foundries as the gate of the ordinary mold will carry it away. Some even prefer to use a ladle narrower at the top than the bottom, to prevent the iron from splashing or chilling.

Molders not aware of the tendency of the iron to chill in the mold may pour a number of castings and not notice their defects until they are shaken out of the sand. When there is any doubt as to the temperature of the iron, it is advisable to try it on a fairly thin casting and observe whether or not it runs out of the vent holes; if it does, it is usually considered safe to use it.

In practically all malleable works a limited number of gray-iron castings are made for their own use, especially when a cupola is used to make pots. It thus sometimes happens that gray iron is poured into malleable molds, and vice versa; the gang foreman must be especially careful to prevent this mistake, as a gray casting is ruined in the annealing oven and a white one cannot safely be used where one of gray iron is required.

CLEANING AND ASSORTING HARD CASTINGS.

29. Hard Tumbling.—In malleable-iron work the term **hard castings** is used to denote castings that have not been annealed, while **soft castings** are those that are annealed.

When the iron has been poured and the castings allowed to cool at least until they have turned black, or until they are perfectly cold, the mold is shaken out and the gates knocked off. The castings and gates are placed on separate piles along the gangways or they may be taken directly to the cleaning rooms and cleaned. The cleaning of ordinary castings is generally done by *tumbling* them in tumbling barrels that resemble those used in gray-iron foundries. The rooms in which the hard castings are cleaned are called the **hard-tumbling rooms** and the tumblers are called **hard tumblers.**

The tumbling creates a large amount of dust, for which reason it is generally done by a night shift, except where an exhaust system is used. With the large number of barrels required in a large foundry, the dust frequently becomes so

thick that it obscures the electric arc lights while the noise is at the same time deafening. It is, however, necessary to remove the sand from the castings before annealing them, as they would not otherwise be salable. The castings, therefore, go directly from the floors of the foundry to the tumbling barrels. When rods are used in the cores of large castings, these are removed before the castings go to the barrels. Small or delicate castings are not placed in barrels with large heavy work, but are cleaned separately.

It is, as a rule, advisable to tumble the sprues in a separate barrel of rather large dimensions, in which slag and skimmings containing globules of iron, called *shot iron*, that may have been carried off with the refuse or spilled in the handling, may also be tumbled. The spaces between the tumbling-barrel staves are very small, hence the dirt must be tumbled quite fine to sift through, and much shot iron that is too large to pass through the opening is therefore recovered.

30. The tumbling barrels, a type of which is shown in Fig. 19 generally consist of two heads *a*, *a*, with a set of

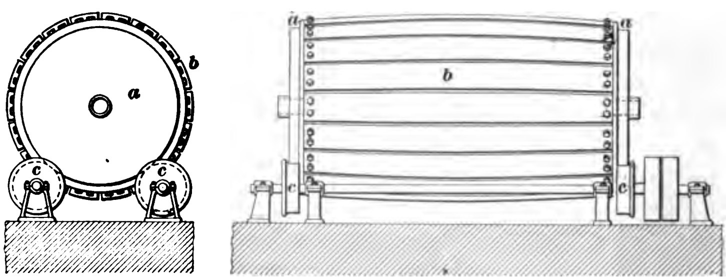


FIG. 19.

staves *b* bolted on them, the whole forming a structure shaped like a barrel. Sometimes, however, they are simply sheet-steel drums. The barrels or drums rest upon friction rollers *c*, *c*, as shown, or are mounted on shafts that run in bearings and are driven by means of spur gearing or friction wheels. A good-sized barrel, about 3 feet in diameter and

5 feet long, usually requires about 5 horsepower to run it when charged.

31. In the best practice the tumbling barrels are equipped with an exhaust system attached to the rolling barrels, which prevents the dust from falling through the cracks between the barrel staves. The air is exhausted through a hollow shaft at the ends of the barrel and clean air is drawn in through the openings between the staves, or if a steel drum is used, through perforations in the head opposite the hollow shaft, only one exhaust opening being used in this case. By the use of the exhaust system, the air in the cleaning room is kept free from dust and the men are able to do more and better work.

Fig. 20 illustrates a plant equipped with such a system. The exhaust pipes *a* leading from the barrels are connected

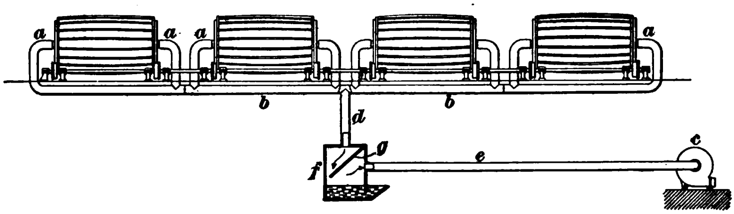


FIG. 20.

to a main conduit *b*, which is connected to an exhaust fan *c*, through the conduits *d* and *e*, and the dust box *f*. The latter is provided with a deflector plate *g*, which causes the dust to drop into water in the bottom of the box. The water space is so constructed that it forms a water seal and at the same time permits the dust to be conveniently removed. This arrangement prevents the heavier particles from passing through the fan, thus preventing the grinding that would otherwise take place and lengthening the life of the fan.

The conduits should be so calculated that equal suction is exerted on each barrel without regard to the number of barrels in use, and blast gates should be provided at suitable points to make the system perfectly flexible. The exhaust fan is placed at the extreme end of the line, and if a water

seal is not used, provision should be made, if possible, to catch the dust in suitable pockets along the line. The finest material, which is drawn through the fan, is blown out into the open air.

32. The tumbling barrels of whatever type they may be are charged with a few hundred pounds of small, star-shaped, white-iron castings, commonly called **stars,** or broken pieces of white-iron sprues, which aid in cleaning the surfaces of the castings. The castings are put in on top of these until the barrels are about half full, when they are securely closed. The barrels are then set in motion and the castings tumbled until they are clean. The average time required to clean the castings is 10 minutes, though it sometimes takes a whole day; by the ease with which the cleaning is done the operator may know whether or not the iron has been overheated in the furnace and burned.

The object of tumbling, as stated above, is to remove the molding sand that adheres to the casting after the molds are shaken out. If the molds are shaken out when the castings are still hot, the sand is frequently burned on so strongly that the subsequent rolling does not remove it, but leaves a polished enamel of sand on the casting. This is due to the oxidation of the iron in the air while red hot and the formation of a silicate of iron with the sand, which is really a slag. If this material should be allowed to get into the annealing pots, where it would be in contact with the oxide of iron packing, it would produce more silicious slag and the castings would have a bad appearance and be unsalable.

The oxidation that takes place in the air when the molds are shaken out while the iron is still hot, and the consequent burning on of the sand, produces practically the same result as a burned heat, that is, a heat that has been oxidized in the furnace before it is tapped out. The internal angles of the castings will have long lines of burned sand, which can be removed only by chipping. As soon as the castings are clean, the barrel is stopped in a convenient position and opened, and the castings taken out.

When heavy castings are tumbled, sticks of wood are placed in the barrel to take the heavy blows of the metal. Sometimes the castings are even wedged into the barrels and the stars allowed to tumble about them as the barrels revolve. A good tumbling-room foreman will study his castings carefully before he puts them into the barrels and will so pack them that there will be the least possible loss by breakage.

33. Sand Blast.—Sand driven at a high velocity against a dirty casting will clean it in a few seconds, and in specialty shops this method, which is known as the **sand blast,** is gradually coming into general use. The apparatus required consists simply of sand reservoirs, with which a compressed-air supply pipe is connected in such a manner that the air drives the sand against the casting. A suitable hose conveys the air and sand to the place where it is to be used. Some auxiliary apparatus is also required for hoisting the sand to the tanks, washing out the dust, and drying it. While this method is very effective, it is exceedingly troublesome, expensive, disagreeable to the workmen, and shows the surface defects of a casting too plainly to be generally appreciated.

34. Cleaning by Hand.—A simple scratch brush, old files, chisels, and hammer are all the tools that are necessary to clean castings by hand. All delicate castings that may be injured by rough handling or by tumbling, or pieces required in a great hurry, are cleaned by this method.

As there is little facing used in malleable-iron molding, the castings are sometimes so thickly incrusted with sand as to be almost unrecognizable. The sand rolled or brushed off is in that case preserved and sent to the annealing room, where it is used to make the mud or mixture that is used to lute, or seal up, the openings about the oven doors, and also sometimes to cover the pots and the openings between the pot sections.

35. Pickling.—Hard castings are also cleaned by immersing them in a solution, called a **pickling solution,**

that removes the sand. This method is of great importance, for if properly done the cost will not be greater than when cleaned by tumbling. Two different solutions are successfully used for this purpose. In the one, sulphuric acid is the active agent, while in the other hydrofluoric acid is used. The latter is preferable, as it dissolves the sand, while sulphuric acid only dissolves the iron under the sand and thus permits it to fall off. The sulphuric-acid solution is made of about 1 part of sulphuric acid to 10 parts of water, and the hydrofluoric-acid solution of 1 part of hydrofluoric acid to 30 or 40 parts of water. Warming up promotes the action of both these solutions. When castings are cleaned by pickling, they are not broken, but they must generally remain in the bath over night, which causes considerable delay, when they must be produced in the shortest possible time.

Unusual precautions must be taken in handling these acids, especially the hydrofluoric, a drop of which in its concentrated form causes a sore that may take about 6 weeks to heal. It is advisable to use rubber gloves when handling it. Where pickling is carried on extensively the solution is kept in large wooden tanks, provided with lead steam siphon pumps to transfer the pickling fluid from one tank to another. Plenty of water must be available to wash the sand and scum out of the tank after the castings have been treated. If the castings are allowed to rust before they are pickled, they will come from the annealing process clean and free from scale.

It is advisable to have an extensive malleable-iron plant equipped with tumbling barrels, benches and chisels for hand cleaning, pickling baths, and possibly the sand blast, in order to be able to use any method that may be most suitable for the work in hand.

36. Assorting.—When the castings have been cleaned, they go to an assorting room, in which they are inspected carefully, defective ones are rejected, the gates chipped off, the castings separated into suitable classes and weighed, after which they are ready to go to the annealing room.

The assorting, or trimming, room is one of the most important departments of a malleable-iron works. Here all the bad work comes to light. If any pieces are rejected, the inspectors go over the bad work with the molders. Experienced men are required to do good work in this department; they must know how to discover hidden flaws, must chip off the gates without digging holes into the castings, yet remove all the unnecessary hard metal. The weighing is all done in this department and the pay of the piece workers made out. In order to do justice to the men and to the firm, men of good judgment and perfect honesty are required. The department should also be well organized in order that the work may be done in the most efficient manner.

A careful account should be kept of the number of good and bad pieces of an order, so that the molding loss of the day may be ascertained. In a well-organized shop this should not exceed 10 per cent. When it runs above this amount a careful investigation should be made to determine the causes, whether from the iron, the molding, or the cleaning, and immediate steps should be taken to correct the fault.

MALLEABLE CASTING.

(PART 3.)

MALLEABLE-IRON PRODUCTION.

(Continued.)

ANNEALING-DEPARTMENT PROCESSES AND EQUIPMENT.

ANNEALING PROCESS.

1. Chemical and Physical Changes Produced. The **annealing process** consists of heating the castings to the temperature necessary to change the carbon from combined to temper carbon, and holding them at that temperature until the change is completed. As the castings are held a long time at a red heat they must be packed in a suitable packing material, as explained later on, to prevent their warping and burning. It has been found, however, that the change in the condition of the carbon takes place independently of the surroundings of the castings if the temperature is just right; but if the temperature is too low, no change takes place; if too high, the castings are burned. It is not advisable, however, to attempt to do practical annealing without packing the castings in a suitable material, owing to the danger of burning them if the temperature should become too high.

When a casting is burned in annealing, the fracture is distinctly crystalline in appearance, but of an altogether different nature than the crystallization of the hard iron. The

crystals are so hard that they scratch glass easily and are often as large as $\frac{1}{4}$ inch on their flat faces. When castings come from the annealing ovens without being fully annealed they should be repacked and reannealed, care being taken to place them in the least exposed portions of the oven to save them from burning. There is a general impression that such castings are spoiled, but this is not the case although they are undoubtedly weakened.

The annealing process to which the white castings are subjected in order to convert them into malleable iron, is intended to change the combined carbon to the form of temper carbon, and to remove a portion of the carbon from the iron lying near the surface, thereby making it approach the composition of steel as nearly as possible. This change in the percentage of carbon is illustrated in Fig. 1,

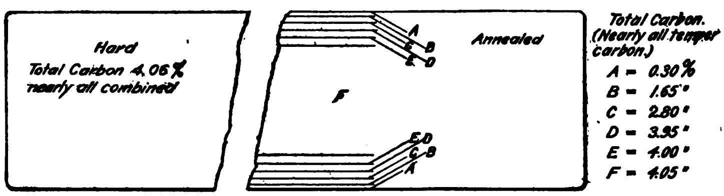


FIG. 1.

which represents a piece of hard iron broken in two and one portion of it annealed. The percentages of carbon in the annealed part, at intervals of $\frac{1}{16}$ inch from the surface, are given in the table at the right of the illustration. The data given were obtained by actual experiment. A sample about $1\frac{1}{2}$ inches thick was selected and cuts $\frac{1}{16}$ inch thick taken over it with a shaper, and the chips of each cut saved and analyzed. Before annealing, the casting contained 4.06 per cent. of carbon, nearly all combined. After annealing, the first $\frac{1}{16}$ inch contained only .3 per cent., the second 1.65 per cent., the third 2.8 per cent., the fourth 3.95 per cent., and the fifth 4 per cent., while the remainder of the piece averaged 4.05 per cent., only .01 per cent. lower than the percentage contained in the hard casting.

2. The carbon in the hard casting was nearly all of the combined form, while in the annealed part it was nearly all in the form of temper carbon. The effect of the decarbonizing, it will be seen, is scarcely noticeable beyond a depth of $\frac{3}{16}$ inch. Pieces that are only about $\frac{3}{8}$ inch thick will resemble steel in their nature; they may even be hardened by heating them properly and plunging them into water. It will, however, be noticed that the skin of the casting is too low in carbon to work well as steel, but it may be enriched in carbon, if desired, by a case-hardening process. It will then have a composition that will behave like steel, when not subjected to excessively hard treatment, and is much cheaper if used for tools that are expensive if forged. Milling cutters, chisels, and wood-working cutters made in this way give excellent service, and many hatchets and hammers are sold as cast steel that are in reality case-hardened and tempered malleable castings.

Another method of recarbonizing the skin of a malleable casting, which is practically wrought iron, consists of dipping the malleable castings into a crucible of melted high-carbon steel. This method is used especially in the manufacture of scissors. Case-hardening with potassium ferrocyanide (yellow prussiate of potash) gives the best results, however. Malleable iron made by the open-hearth process, in which the carbon is near the minimum limit, shows a nice black fracture. When heated to a red heat and plunged in water its structure will be changed to the finest steely grain and every sign of blackness will be gone, the temper carbon seemingly being recombined. The strength, however, is not great. In straightening warped castings, therefore, they should not be heated, as the recombining of the carbon again causes a white fracture and tends to destroy the power to resist shocks. They are therefore liable to be condemned and returned by the purchaser.

3. Extent to Which Annealing is Carried.—The extent to which the annealing process is carried depends largely on the amount of time available. When work must

be produced in a very short time and the duty of the castings is not too exacting, the time during which they are allowed to remain in the annealing oven is comparatively short. On the other hand, when the conditions permit or require it, the time is lengthened accordingly. In the case of emergency work, when it may be necessary to ship the castings the day after they are cast, they may be placed over night in an open-hearth melting furnace, the temperature of which is kept so that the castings are just short of a full red heat; in the morning the castings will be annealed sufficiently to ship, but the strength will be below that of castings that have been treated in the regular way. Castings annealed by this quick method should not be cooled in lime; in fact, lime should be kept away from the annealing room entirely, as it tends to eat out large blotches from the skin of the castings, and thus destroy their appearance.

4. Packing Materials.—Castings may be annealed when packed in sand, fireclay, or any other inert substance, but the skin will not be decarbonized to the same extent as when packed in oxide of iron. The object of packing in oxide of iron is therefore not only to hold up the form of the work, but to assist in removing some of the carbon. How this is done is yet in doubt. Some investigators claim that the oxygen penetrates the castings and actually burns the carbon out of them; others think that the iron burns first and that the carbon rather diffuses out in a manner similar to that in which sulphur is known to leave a casting on continued heating.

The packing material generally used for iron melted in a furnace is puddle scale, although rolling-mill scale is also used with good results. For iron melted in a cupola, hematite ore, pulverized, is better. A temperature of about 1,600 or 1,800° F. is required to anneal cupola iron, while furnace iron will anneal at a temperature as low as 1,250° F. and the temperature should not exceed 1,400° F. Hematite ore can be heated readily to the highest temperature given above without baking seriously, while puddle scale, being a

silicate of iron mixed with oxide, will fuse at 1,600° F., burn on the casting, and in melting will run between the castings. This tends to warp and bind them together, forming a mass that cannot be used in a malleable-iron foundry, and must usually be sold to blast furnaces at a very low price.

5. The necessity of thoroughly cleaning hard castings becomes apparent in the annealing process. If any of the molding sand is allowed to remain upon them, when subjected to a high temperature, it combines with the iron oxide in the scale and increases its fusibility. The silicon that enters the packing material soon works down to a fine dust; to prevent its accumulation in sufficiently large quantities to become seriously objectionable, the scale should be screened occasionally and the finest dust thrown away. When the scale has been overheated and baked together for a time there will be little dust to screen out.

In America, puddle scale is used almost exclusively as an annealing-furnace packing by the founders producing the heavier classes of work. This material, which is the slag squeezed out of the iron produced by the puddling process, always contains lumps of iron, which, however, are not objectionable. It should be clean and free from fine dust and fairly dry when received. When the first supply has been purchased, there should be no need of buying any more, as the pots in burning away furnish flakes of oxide of iron, which, when crushed, form ideal scale. There is a tendency for the scale to gradually work itself into a better oxide, as the silicates are screened out in the form of dust, leaving a clean, pure oxide of iron behind. This tendency may be hastened by sprinkling the scale with sal ammoniac dissolved in water after each time it has been used, to rust it thoroughly. This practice, however, is now abandoned almost entirely in the larger works, and more oxide in the scale is obtained by adding steel borings in order to let the oxidation attack these, thus sparing the castings.

When the scale has been used for some time, it should be in the form of grains about the size of a small pea. In this

form it readily runs between the castings and packs them tightly. Larger pieces cause air passages between the castings and also allow them to sink down and become warped; smaller pieces give trouble by baking together when the temperature becomes a little too high.

ANNEALING POTS AND FURNACES.

6. Annealing pots consist of three or four cast-iron boxes, without bottoms, set on a stool. They are preferably made of a special iron capable of resisting high temperatures, although many pots used are made from the regular malleable-iron mixture. The mixture, when especially prepared for this purpose, has been given in *Malleable Casting*, Part 1. Their shapes may vary considerably; they may be square, oblong, round, or have special shapes to suit the castings going into them; the form generally used, however, is shown in Fig. 2. The inside dimensions are 16 in. × 22 in. × 15 in.; the thickness of stock tapers from 1 inch down to $\frac{3}{4}$ inch, the taper being intended for draft in molding. One form of the stool on which the pots rest, which is cast of the same mixture as the pots, is shown in Fig. 3. The top plate *a* extends several inches beyond the end feet *b*, *b*, so that the prongs of a truck may be run under them for the purpose of picking them up and carrying them to and from the annealing oven.

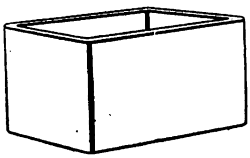


FIG. 2.

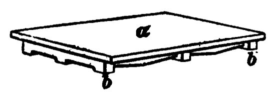


FIG. 3.

7. Packing the Annealing Pots. — In charging annealing pots, one box is set upon a stool and a few shovelfuls of scale thrown in to cover the bottom to a thickness of about 1 or 2 inches; then the castings are laid in closely and in such a way that they will readily resist any tendency to sag downwards. About 1 inch of scale should lie between the pot and the castings. The packer now fills in scale, stamping it down with bars, at the same time pounding the

box on both sides to settle down the scale into a tight mass. Layer upon layer of castings go in in this way. When the first box is filled, another box is placed upon it, then a third, and finally, if desired, a fourth one may be added. When long, slender castings are to be annealed, the fourth box is required.

When the packing is finished, either a plate of iron may be put on the top, or it may be covered with about 1 inch of mud, which is made up of the sand removed from the castings in the hard-tumbling room mixed with enough water to make a stiff paste. At the same time the cracks between the boxes, in fact, all openings, may be mudded up and the pot turned over to the charging gang. If mud is used, it must not be allowed to mix with the scale, and must be carefully cleaned off before the pots are emptied. This takes considerable time, and the pots are therefore often left open, the scale being simply rounded up on them. This, however, causes the scale to cake, but it is claimed that it is less expensive to tumble the scale occasionally than to clean off the mud after each heat.

In packing the pots, the following precautions should be taken: Delicate castings should go in the middle of the pot, where the heat is not so intense as at the top. If large, heavy castings are packed, light ones may go beside them with safety. If the castings are too thin to bear a weight above them, they may be placed in the upper part of a pot, but must be placed in the portion of the furnace farthest away from the fire; the same is true of castings that must be reannealed. When work is packed that it is essential to trace, or locate, immediately when the furnace has cooled, it is customary to place a brick on top of the pot, which acts as a good marker. The pots can also be streaked with mud, which is red and quite legible on the black background of the pot, when it emerges from the oven. Fig. 4 shows a pot that is ready to be placed in the oven.

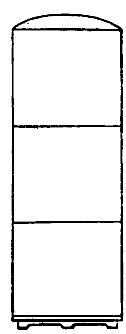


FIG. 4.

The course of the hot gases in an annealing oven is downward, so that the top of the pot is the most exposed to the action of the heat and hence wastes away more rapidly than the bottom. The annealing-room foreman must therefore be careful to work the upper sections of the pots gradually into the lower sections, so that an average service may be obtained from them all. New pots are liable to crack when first subjected to the high temperature of the annealing oven, but if they do not crack the first time, they will probably give good service. Unless a crack runs across opposite sides, the pot can still be used by placing a piece of an old annealing pot inside, thus covering up the crack, and luting it well with mud. Eventually, however, it will open up too much to be made serviceable in this way and must be discarded.

8. The **life of annealing pots** varies considerably. If the iron of which they are cast is too gray, they will last only 3 or 4 heats; if the iron is good, the average life is about 9 heats, when coal, oil, producer gas, or natural gas with no regulation is used. With natural gas carefully regulated to a low presssure and a constant supply, the actual average of a furnace full of pots has been found to be 19$\frac{2}{3}$ heats. This shows clearly that care in the management of the fires may effect a great saving in cost of pots alone.

The sides of the boxes will gradually bulge out and become rounded, the edges will waste away, and finally it will pay to discard them. They can be cut up and remelted in the regular cupola charge for annealing boxes; but this is not advisable, as they are heavily charged with oxide, which if used for the new boxes makes them less able to resist the high temperature.

9. Annealing Ovens.—The general principle of the annealing oven is the same as that of a down-draft furnace. Fig. 5 shows the arrangement of an oven equipped for the burning of natural gas. The gas and air enter the oven at one end *a*; the flame strikes the wall *b* and travels up, strikes the vaulted roof *c*, and is deflected downward; the hot gases then strike the pots *e* and pass down through

the flues *f* in the bottom of the oven and out through the flues *g*, *h* to the chimney *i*. A damper *j* is placed in the chimney flue *h* to regulate the draft.

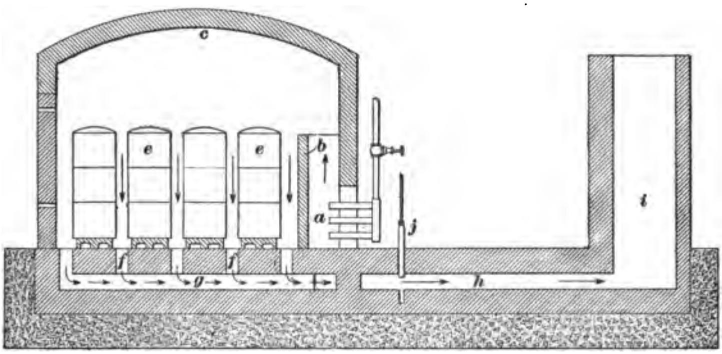


FIG. 5.

Ovens are usually built in batteries of five or six, if of a large size, and ten or twelve if small. They are built against one another and the tie-rods extended all along the top; much material is saved by this arrangement. The ovens are moreover kept fairly warm during the charging, as alternate ovens are usually kept in fire all the time, in order to keep the draft uniform, especially when they all communicate with one stack.

The temperature of an annealing oven is not as high as that of a melting furnace and it can be built of much cheaper material; No. 2 firebrick may be used for the lining and common red brick for the outside walls. The connecting walls between two ovens are made of 9-inch red brick faced with 4-inch firebrick, while the crown is made of 9-inch firebrick covered with 4-inch red brick, as shown in Fig. 6. Great care must be taken to get a good bond, or

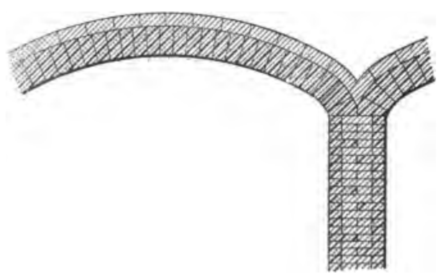


FIG. 6.

joint, between the two kinds, as the red brick is smaller than firebrick. The high heat has a tendency to disintegrate the brickwork eventually, and it must constantly be kept in repair by a bricklayer.

The floor of ovens that are charged by means of a truck is made of large tile, which covers the flues in which the escaping gases circulate before going out through the chimney flue, thus keeping the bottom hot. The floors of ovens charged by means of a crane are made of ordinary firebrick with a corresponding cheapening of the first cost.

10. The oven doors shown in Fig. 7 are made of heavy wrought-iron frames *a*, *a* well tied together with cross-braces, the spaces *b*, *b* being filled with firebrick. The doors shown loosely fit into the door frame *c* and have a space *d*, the width of one brick, between the halves. The doors are lifted by inserting the prongs of the charging truck into the openings *e*, *e* at the bottom, which are provided for this purpose. The doors are also frequently hung on heavy hinges, so that they can be swung out of the way while charging or discharging. The hinged doors fit against the outer faces of the frames, and when closed the openings along the edges are made air-tight by mudding them up. The doors when hinged are usually built up of angle and T iron, so as to hold the brick more firmly. A space the width of one brick is left between the halves, as in the doors shown in Fig. 7.

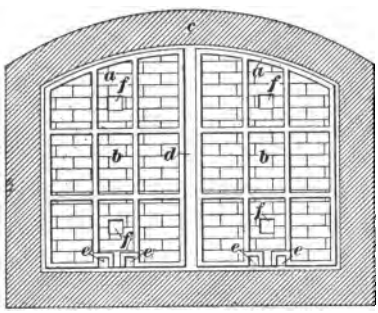


FIG. 7.

Four peep holes *f* are made in the doors in order to observe the condition of the flame in the upper part, and the heat of the pots in the lower part of the furnace. The firing is all done at the one side of the rear of the furnace, hence a good view is obtained by looking through the upper holes.

The oven tender or foreman regulates the fire by the length of the flame he sees, as well as the temperature. The front of the oven at the bottom is the coldest part, and tests are therefore made at this point with a pyrometer, to see if the temperature required to perfect the process is attained.

11. Fig. 8 shows a plan of the bottom of the oven, in which *a* is the firebox, or combustion chamber, *b*, *b* are the

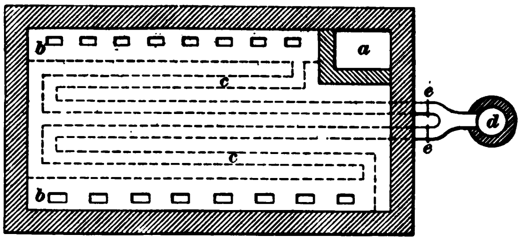


FIG. 8.

openings through the floor into the flues *c*, *c*, which lead to the chimney *d*. Dampers *e*, *e* are placed in the flues near the chimney to regulate the draft. The openings *b* are regulated by the oven tender, who covers as many as may be necessary to distribute the heat as required. The tops of the flues are often covered by arched brickwork, but this is quite expensive. A less expensive method of covering them is illustrated in Fig. 9, the flues being shown at *a*.

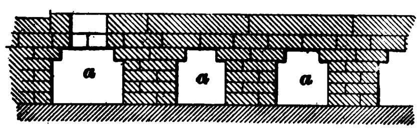


FIG. 9.

The dampers *e*, *e*, Fig. 8, are made of flat cast iron and hung in cast-iron frames. They are counterweighted, and should be kept closed as far as possible, as too great an opening permits a great loss of heat from the oven.

In order to obtain a more uniform temperature throughout, some ovens have air spaces in the side walls to prevent radiation, and others have double crowns, the hot gases being allowed to circulate between them. While these ovens work very well, both the first cost and the cost of

maintenance are very high, and there is some question among malleable-iron experts whether they are really economical. It is, of course, desirable to have a uniform temperature in the oven, but it has been found that when the bottom is properly cared for there is only a difference of 50° F. between the hottest and coldest parts of the best ovens of this class, and about 200° F. in the ordinary ovens.

PROVISIONS FOR HEATING ANNEALING OVENS.

12. The **fuel used in annealing ovens** may be either coal, coke, natural gas, producer gas, or oil, while recently some experiments have been made with coal dust. Each fuel requires somewhat different treatment in order to produce the best results.

13. Coal-Burning Equipment.—Fig. 10 shows the firebox for ordinary coal or coke burning, *a* being the grate, *b* the fire-door, *c* the ash-pit door, *d* the bridge wall, and *e* the crown of the oven. The firing with this style of furnace does not differ from the method of firing an ordinary steam boiler, except that the fire is slow. A thick bed of fuel is used and the air passages kept closed as much as possible, in order to keep out all unnecessary cold air. The fires are cleaned periodically and a steady heat maintained. Soft coal gives the best results, as it burns with a long smoky flame; when the furnace is once hot, this smoke is readily consumed and gives no trouble. The supply of coal should be convenient to the ovens, which in a large foundry are usually arranged along the side walls with the fireboxes opposite windows through which the coal

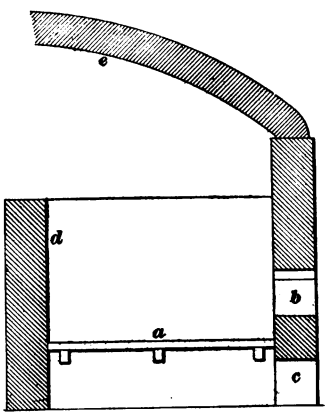


FIG. 10.

is brought into the building. When a railroad siding can be brought along the side of the building, so that the coal can be transferred directly from the cars to the piles in front of the furnace doors, it greatly reduces the cost of handling.

The furnace shown in Fig. 10 is applicable to single ovens only. When the ovens are built double a slightly different arrangement is used. Fig. 11 (*a*) shows an end view and

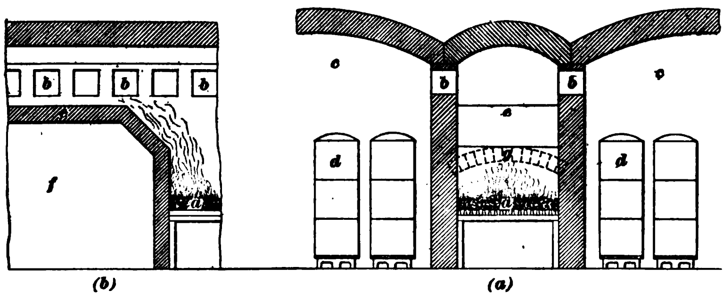


FIG. 11.

Fig. 11 (*b*) a side view of the firebox used in this case, in which *a* is the grate, *b* the openings through which the hot gases pass from the firebox into the ovens *c*, and *d* annealing pots in the position in which they stand during the annealing process. A bridge wall *e* carries the flame upwards toward the ports *b*. The space *f* beneath the bridge wall is filled with clay, broken brick, or any other material that will not press outwards when it is baked. An arch *g* is built in, both at the front and the back of the furnace, forming the top of the fire-doors at the front and an opening to the space below the bridge wall at the back. This firebox is really a special furnace built in between the side walls of two ovens. While the results obtained from this system are generally good, it takes longer to heat the ovens than in the case of single ovens, and any difficulty with the regulation of the draft will cause the castings to be imperfectly annealed in at least one of the ovens. A separate fire for each oven is therefore preferable, even though it takes the room of several pots.

14. Gas-Burning Equipment.—When natural or producer gas, oil, or coal dust is used as a fuel, the space occupied by the grate may be considerably shorter than when coal is used, as in these cases only a combustion chamber is required.

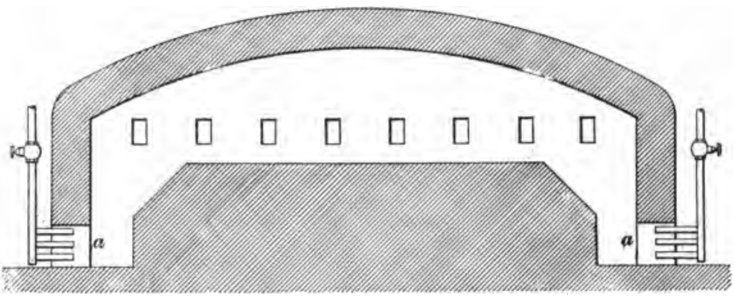


FIG. 12.

In Fig. 5 the ordinary arrangement for natural gas is shown. In the case of double ovens there is a firebox *a*, *a* at each end, as shown in Fig. 12, in the space between the two ovens.

In some works, especially where natural gas at a high pressure is available, it is allowed to enter the oven directly, an air mixer being attached to the end of the gas pipe. This practically does away with the firebox altogether, and therefore increases the capacity of the annealing oven. Fig. 13 illustrates the positions of the burners *a*, *a* with

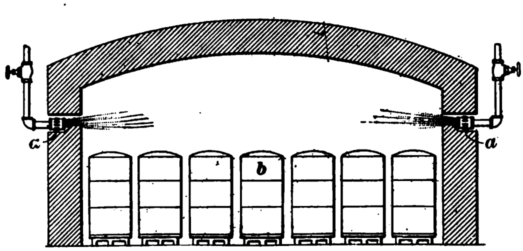


FIG. 13.

reference to the annealing pots *b*. This method is rather hard on the pots, unless there is plenty of headroom over them, in which the burning gases may become somewhat diffused before they reach the pots.

The principle of the air mixer commonly used is illustrated in Fig. 14. The gas enters through the tube *a*, into the chamber *b*, where it is mixed with the air drawn in through the openings *c*, the mixture passing out through the nozzle *d*, at the mouth of which it burns in a blue flame. The flow of air is regulated by means of a plate *e*, with holes corresponding to the holes *c*, which may be turned so as to make the opening of such a size that the required amount of air will be admitted. While a gas mixer is desirable when heating an oven with a natural-gas burner, experience has shown that after the full heat is obtained the direct flame gives the best heat. When the gas comes in under low pressure no trouble will be experienced in obtaining a perfect combustion. The gas is burned farther in the furnace and a more even distribution of the heat is therefore obtained. With a blue flame there is an intense local heat at the end of the oven nearest the burner, but too high a temperature must be maintained at that point to produce a sufficiently high temperature in the colder portions of the oven to anneal properly, and the parts subjected to the excessive temperature are liable to be injured thereby.

FIG. 14.

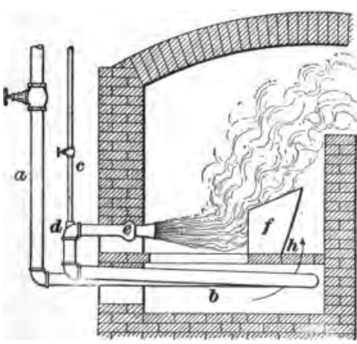


FIG. 15.

15. Oil-Burning Equipment.—Oil may be sprayed into a combustion chamber either with steam or compressed air. Air gives the best results, but opinions differ greatly as to the best pressure to be used, some advocating a pressure of 6 ounces, while others maintain that a pressure of 40 pounds per square inch will give the best results. Fig. 15 shows the arrangement of

the firebox of an oil-burning oven. The air enters the oven through the pipe *a* and passes through a coil of pipe *b* in the firebox, where it becomes heated and comes up and meets the oil that enters through the pipe *c*, at *d*. The oil and air then pass through the burner *e* and ignite as they emerge from it. The oil usually enters the burner under a pressure of about 45 pounds per square inch. The burner ordinarily used is shown in Fig. 13, *Malleable Casting*, Part 2. A tile *f* placed on end before the burner, breaks the force of the air and oil and protects the bridge wall *g*. It also mixes the oil and air intimately, and thus aids the combustion. An air passage *h* is provided behind the tile to furnish more oxygen to the flame and carry it upwards. The air spaces shown at the entrance of the firebox are usually reduced by inserting loose firebricks, which are added or removed according to the judgment of the oven tender.

One of the troubles met with in the burning of oil is the formation of great masses of gas carbon, which is almost as refractory as graphite and must be removed from time to time. An oil strainer must also be placed before the burner so that the small orifice through which the oil is forced may not be clogged by the particles of solid matter that are liable to collect in the supply tanks or pipes. Oil burning is excessively hard on the parts of the furnace nearest the burner. The heat is even more intense than that of natural gas when the mixer is used, and in order to obtain a sufficiently high temperature in the cooler parts of the oven, it is often necessary to have the flame at the burner so hot that the roof of the firebox is injured.

16. Coal-Dust-Burning Equipment.—Coal dust is now used as a fuel for annealing ovens in malleable-iron works in this country, although its use is yet in its experimental stage. The apparatus used in burning it resembles the oil burner shown in Fig. 15, except that the oil pipe *c* is replaced by a coal-dust hopper. The coal is ground so fine that the ashes formed either settle in or pass out through the chimney, scarcely ever giving trouble in the oven flues.

Although this method of heating the oven has not yet been proved a complete success, it is thought by some malleable-iron experts that it may, when perfected, prove very valuable.

17. Producer-Gas-Burning Equipment.—Producer gas is probably the most difficult fuel to use, but when the entire apparatus is once running successfully it is equally as good as either natural gas or coal. As the quantity of air and gas entering the oven should be as small as possible in order to maintain the required heat in the oven, the quality of the gas must be good. If the quality is poor, so much air is drawn in with it that the oven is not heated properly and the annealing is not done satisfactorily. The simplest method of burning producer gas is shown in Fig. 16, in which *a* is

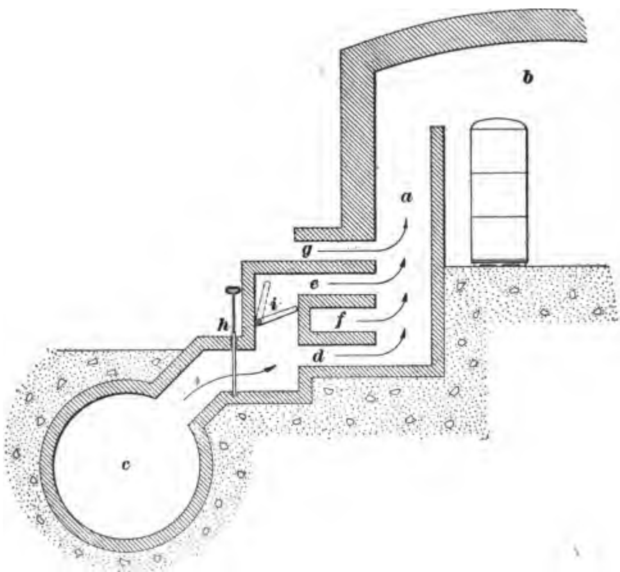


FIG. 16.

the combustion chamber, or firebox, and *b* the oven. The gas enters the combustion chamber from the main gas flue *c* through the gas ports *d*, *e*, while the air enters through the ports *f*, *g*, the air being admitted over the gas. A damper *h*

is placed in the gas connection to regulate the flow of gas or cut it off entirely. Two sets of gas and air ports enter the combustion chamber in order to insure a sufficient supply of each. In burning producer gas tar is formed and runs down, tending to close the lower ports. As these become clogged the upper ones are opened gradually, thus maintaining a constant supply; the damper *i* in the upper gas connection is provided for this purpose. The entire burning apparatus is enclosed in a cast-iron box made of plates bolted together. This arrangement gives very satisfactory results.

Another form of producer-gas-burning apparatus for annealing purposes, which has proved very successful, is shown in Fig. 17. In this case, only one air inlet port *a* and one gas inlet port *b* are used. The gas supply is regulated by means of a valve *c*, which is controlled by a hand wheel and screw *d*, and the air supply, by opening or closing the air channel. A damper *e* is also provided for cutting off the oven from the gas flue *f*. This arrangement of the burning apparatus gives even less trouble from the accumulation of tar than that just described. The valves and ports of both, however, must be burned out at the same time as the flue, or they will soon become choked with soot and tar. There is also a tendency for the flame to strike back into the ports and flues, causing a precipitation of carbon in the flue, between the gas main and the ports, which sometimes necessitates tearing them out, as this carbon will not burn out with the soot, being almost as refractory as the oil carbon referred to. Great

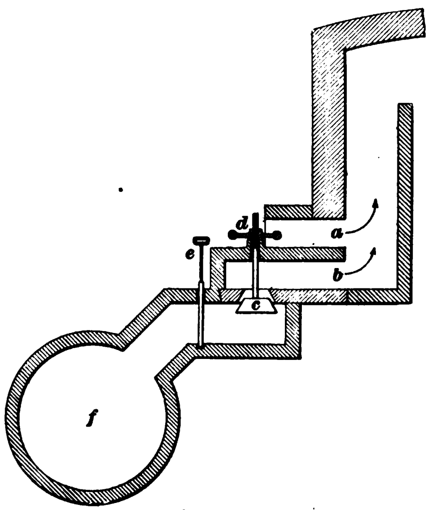


FIG. 17.

care must be taken to inspect the gas boxes very frequently to see that the gas does not burn within them. If it does, the flues will soon become choked and all the ovens may have to be shut down long enough to remove the trouble. A part or even the whole charge of the oven may be spoiled and much delay and annoyance caused.

18. The Oven Chimney.—In the most recent practice, ten or more annealing ovens are connected with one chimney, generally about 80 feet high and about 4 feet inside diameter, with a 4-inch lining. When the heats are steady, such an arrangement gives good results and effects a considerable saving in both the first cost of the plant and the cost of repairs. When, however, the works are liable to be run intermittently, it is often advisable to have a small stack for each oven, as in that case there will be no loss of fuel and time in starting the draft. When several ovens are connected with one chimney, considerable trouble is often experienced from this cause. In starting up the ovens connected with a single chimney, a good fire lighted in its base will assist considerably in producing a good draft.

OPERATING ANNEALING OVENS.

19. Charging the Ovens.—When the annealing pots are properly packed, so as to prevent air passages forming in the packing material, they are taken to the oven by means of a **charging truck,** one form of which is shown in Fig. 18, which consists of two arms *a*, *a* with handles *b*, *b* at one end, and prongs *c*, *c* at the other end, mounted upon a truck *d*, *d*. The arms *a*, *a* are so connected to the axle of the truck that when the lever *e* is in the raised position shown, the prongs *c*, *c* readily run under the lips at the end of the stool under the pots; and when the lever is lowered so as to catch under the hook *f*, the pots are raised from the floor and may readily be carried to the oven. The small wheels *g*, which turn on a pivot, support the handles, thus facilitating the handling of the truck.

A gang of men take the charging truck, and raising the lever *e*, let the two prongs *c*, *c* down to their lowest position and run the truck under the pot, the prongs catching under the lips of the stool. The lever is then drawn down and caught under the hook *f*; this lifts the prongs high enough to raise the pot off the floor. The truck is now pushed into

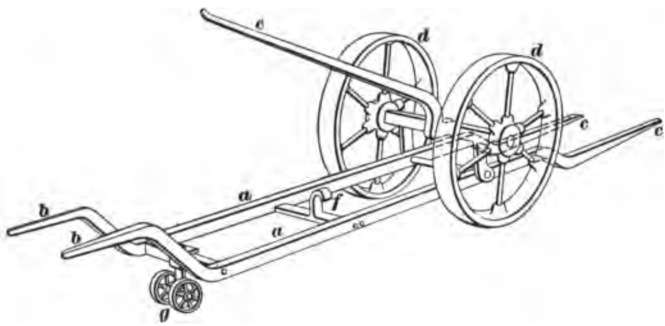


FIG. 18.

the oven and the pot lowered in the position desired. Six men are usually required for this operation. The truck is made long enough to reach to the rear of the oven, and yet extend out far enough to enable the men to remove the last row of pots from the oven while it is still quite hot, without being burned. The same truck is also used to remove the oven doors, when they are not hinged. They are held upon the truck by the men by means of suitable iron hooks, to prevent their falling over.

Another shorter and lighter truck of the same general design may be used to carry the pots from one place to another in the annealing room, the great length of the charging truck making it inconvenient for this purpose. A light electric or pneumatic traveling crane is also used in some foundries to carry the pots about the annealing-room floor. Such a crane may be operated either from a cage or from the foundry floor.

20. Firing the Ovens.—The oven having been charged, the doors are closed, the cracks are carefully filled

with pieces of brick, commonly called *bats*, and mud. If gas is used as a fuel, oily waste is lighted and placed in the firebox and the gas turned on; if coal is used, the fires are started without any special precautions. In firing with gas, it occasionally does not ignite at once, the draft carrying it into the oven too quickly. This usually results in an explosion, which frequently ruins the roof of the oven, blows out the doors, and sometimes causes fatal injuries to men working near by.

When the fires are first lighted, the dampers are kept partly open, and nothing but smoke is seen in the oven and coming out of the chimney. In about 6 hours the smoke becomes lighter; in 12 hours a faint redness should be visible, with but little smoke; and in 24 hours a good heat should be obtained. In 36 hours the oven should be heated to the required temperature, and a *pyrometer*, which is an instrument by means of which high temperatures are measured, used to regulate the temperature properly.

With furnace iron, the coldest part of the oven should never fall below 1,250° F., and it should preferably be 1,350° F., but not over. In annealing, the temperature should be raised as rapidly as possible to full heat, then held stationary at this temperature for the required time, which may vary from 4 to 6 days, and finally allowed to cool down as slowly as time will permit; the best iron is obtained in this way. Thus, with a 6-day anneal, 36 hours is required to heat up and 24 hours to cool down, leaving 84 hours, or 3½ days, for the full heat. Good work has, however, been produced in 72 hours, and other work has taken as much as 216 hours to anneal properly.

21. Measurement of Oven Temperatures.—Two different pyrometers are used for this purpose, the old *Siemens water pyrometer* and the *Le Chatelier pyrometer*. The former is very simple, but requires considerable time to obtain the temperature accurately, while the latter indicates the temperature more quickly, but is more expensive.

The **Siemens water pyrometer** consists of a copper vessel containing a weighed quantity of water, whose temperature is noted by a thermometer placed within. A weighed copper ball, or cylinder, is now heated in the oven for 10 minutes and quickly plunged into this water, shaken up, and the rise in temperature noted. A scale that is provided with the thermometer indicates the temperature of the copper ball. Suitable precautions should be taken to prevent the escape of heat during this process, which, if carefully done, indicates the temperature within 25° F. As it is essential that the temperature of the pots and not that of the oven be taken, the copper cylinder is placed in an iron holder against the coldest pot in the oven, that is, in the front row, farthest from the fire, and opposite the lower peep hole, as shown in Fig. 19, in which *a* represents the copper cylinder, *b* the holder, *c* the annealing pot, and *d* the peep hole in the door. The copper cylinder is then surrounded by iron and touches the pot. There can thus be no overheating, and in about 10 minutes the temperature of the copper is practically equal to that of the pot, and the test may be completed. It is also well to cover the peep hole with a cover-plate *e* while heating up the cylinder to prevent an inward draft of cold air. When a number of tests is to be made, three or four rods can be kept heating continuously; but in this case care must be taken that the required amount of water is used each time, as there is some loss whenever the cylinder is plunged in and removed.

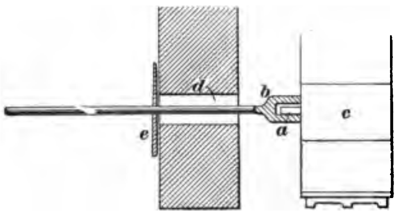


FIG. 19.

When cupola iron is to be annealed, this pyrometer cannot be used advantageously, as the temperature required is too near the melting point of copper. The experienced annealer therefore usually looks for a crack in the brickwork and notes the whiteness of the joints, which indicates quite closely the temperature within the oven. It is always best

to have two or more men responsible for these temperature observations, as the eyes of one man may occasionally change and eventually lose their power to observe the temperature accurately.

The **Le Chatelier pyrometer** consists of a wire of platinum and another wire of an alloy of platinum and 10 per cent. of rhodium. These wires are fused together, and when the joint is heated a current of electricity is produced that is proportional in strength to the temperature applied. It is necessary therefore simply to measure the current of electricity with a galvanometer suitably calibrated. As it takes only a few seconds to take the reading, the instrument is very valuable in connection with a malleable-iron foundry.

22. Discharging the Ovens.—When the annealing process is complete the fire is shut off, the oven allowed to stand a little while to lose the intensity of the heat, and the bricks loosened from between the doors. This allows cold air to enter, and reduces the temperature sufficiently to allow the doors to be taken away in about 12 hours after shutting off the fire. The pots may now be taken out slowly and stacked in long rows, where the contents may be dumped out conveniently, the charging truck being used for this purpose.

23. Shaking Out the Pots.—When the pots are cold enough to dump, the clay and sand luting, if any is used, is carefully removed so as not to contaminate the scale; the pots are generally tilted over by means of a crowbar and hammered to break off the flakes of scale that may adhere to them. The pots are then removed and placed where a new lot of castings can be packed into them, and the annealed castings carefully picked out of the scale. The hammer must frequently be used to free the castings from the scale, as they are often baked together quite firmly and the holes filled up with burned scale. When the castings have been picked out, they are removed to the cleaning department.

A more convenient method is to raise the pots with an air hoist, and to rap them on the side with a heavy hammer until the scale becomes loosened and the scale and castings fall out.

24. Disposition of Castings and Packing Material.—Small castings and scale, as they come from the annealing pots, are sometimes put directly into a coarse tumbling barrel with perforated staves and tumbled until the packing has sifted out and only the castings remain. The castings are shaken out of the annealing pots into carrying boxes, from which they are emptied into the tumbling barrels.

When the scale is not put into tumbling barrels with the castings, it is preferably screened in a coarse revolving screen into which several bars of iron have been placed. These break up the lumps and cause the scale to pass through the meshes of the screen. Any stray castings are also caught by this process. In some foundries the scale is spread, wetted down with sal-ammoniac water, and allowed to rust over night; the next day it is used to pack a new lot of hard castings. In many large foundries the use of sal-ammoniac water has, however, been discontinued, but wrought-iron or steel borings are added to the scale, in order to keep it rich in oxide and in a measure prevent its sticking to the casting.

DISPOSITION OF ANNEALED CASTINGS.

25. Soft Tumbling.—It is necessary after the castings come from the annealing room to tumble them in order to remove any scale that may adhere to them. Since, after annealing, the castings are commonly said to be soft, this process is called **soft tumbling.** The simplest method of tumbling is to place the castings in tumbling barrels, add a quantity of small pieces of broken annealed castings, and let the whole revolve until the work is clean and polished. The annealed pieces of scrap usually consist of test plugs broken from large castings. The temper carbon and soft iron of the annealed pieces rapidly produce a bright, black, polished surface. The tumbling must not be continued too long, however, as the sharp corners are rounded too much, which makes them unsalable.

Generally the soft-tumbling room is separate from the hard-tumbling room; when, however, a foundry is crowded with orders the work is adjusted between the two as may be most convenient. When this is done, great care must be taken to keep the hard and soft castings separate, as the average man cannot distinguish between an annealed and a hard casting, and unannealed work is therefore sometimes shipped and used with disastrous consequences. Annealed castings are also sometimes annealed over again. Continued practice will, however, in time enable the annealing-room men to distinguish between the two kinds.

When the castings are rather delicate, blocks of wood are thrown into the barrels to protect the castings in a measure from being bent and pounded out of shape. Very light castings that are to be polished or plated must receive special care. When they are to be highly polished in the tumbling barrels, only a part of the pieces of soft iron ordinarily used are put in the barrel, but with these are put pieces of leather, old shoes, and similar materials. This produces a polish that resembles that of work which has been specially buffed piece by piece; small buckles for straps, pistol parts, general hardware, etc., are finished for the makers in this way.

26. Finishing and Assorting.— Where specialties are made of light work, considerable special machinery may be introduced advantageously for the purpose of polishing, assorting, and handling the work. The form of the specialty will usually readily enable one to decide where and how such special machinery can be used economically.

This class of work should need no grinding; all gates should be trimmed off nicely before annealing. If, however, this has been neglected, the castings must be ground and chipped before they are assorted. If there are parts of gates that were not completely chipped off when the casting was hard, it must be done now. If the molder has rapped the pattern too hard and the casting is therefore too long,

part of it must be ground off. It is therefore necessary to have a grinding room for annealed castings. A large room of this kind is, however, always a sign of laxity in the pattern shop, foundry, or trimming and inspecting room.

Two kinds of emery grinding wheels should be provided, some heavy ones and others of medium size. The large wheels are preferably of the variety provided with large cast-iron cores. For general work the wheels should be mounted on substantial iron stands; for very heavy work, however, wooden stands are preferable, as they tend to decrease the vibration. Two wheels may be mounted on each grinding head, thus economizing in both space and cost of machinery. The speed should be high enough to do fast cutting. Medium to soft wheels give the best results; hard wheels glaze so rapidly that they must be dressed too often. The wheels should not be used until the diameters are too small, for the cutting speed is reduced to such an extent that the iron is not ground off freely, and a new wheel will soon pay its cost in the greater amount of work that can be done with it in the same time.

When wheels with rubber as a binding medium for the emery are used, special care must be taken to clean the dust from the wooden girders of the grinding room, for any leakage of the roof is liable to rust the fine iron dust so rapidly that a red heat is produced, thus igniting the particles of rubber in the dust and burning the buildings.

27. From the grinding department the castings go to the chipping or finishing department. Here all fins too large to be ground away are chipped off, and holes left imperfect by bad cores are cleaned out and if necessary drifted to size with specially constructed tools. A number of chippers' vises of large sizes are used for this purpose. The castings are brought to the chipper and placed on the bench; when finished they are thrown on a pile on the floor. Suitable bins for storing the different kinds of castings are a great convenience and save a large amount of time in

filling orders. Occasionally it is found cheaper to drill some holes than to core them out; when this is the case they are drilled in the finishing room, one or more drilling machines usually being provided for this purpose. Then again a casting may come from the foundry with large lumps of iron on it that could not safely be trimmed off before annealing, owing to the danger of injuring the casting; for this class of work a shaper is very serviceable and should be included in the finishing-room equipment. If, however, the cost of finishing such castings is greater than the cost of a new mold, the casting should not be allowed to go to the annealing oven.

A small drop hammer should also be provided for straightening castings that have become warped in annealing. The straightening should always be done cold if the casting will stand it, although if necessary it may be heated gently. Great care should, however, be taken if it is heated, as the strength is liable to be injured. The straightening may be done by means of suitable forms made of gray iron, or if the quantity warrants it, a drop hammer furnished with suitable dies may be used. It is often cheaper, when a bent piece is required in large quantities, to cast it flat and bend it afterwards on a form; this is frequently done in making brake-shoe keys, the levers for air-brake cocks, etc.

28. Inspection of Test Plugs.—In order to test the quality of the iron after it is annealed, test pieces, generally called **test plugs,** which are simply small projections, about $\frac{3}{4}$ in. $\times$ $\frac{1}{2}$ in. $\times$ 1 in. long, are cast on the more important work. Sometimes two or three of these are located in critical places. In railroad couplers especially, their constant use is important, as underannealed or overannealed or otherwise undesirable work can be thrown out. These test pieces are all removed in the chipping room, and the fracture is carefully inspected. The normal fracture should have a black velvety surface in the interior surrounded by a band of dark gray about $\frac{1}{16}$ inch thick, and this in turn is incased in a band of white not more than $\frac{1}{64}$ inch thick. If this band of white is thicker, it is an indication that the hard casting

is too low in silicon, commonly said to be too "high," the crystallization of the casting is too open, and the oxidation during the annealing process penetrates too deeply. If the band of white becomes $\frac{1}{8}$ inch thick, the castings will be found weak and no longer safe for very exacting service. As the white band becomes thick the gray band disappears. This gray band is the rim of crystals at right angles to the skin, regularly formed and therefore more open to the loss of carbon. The interior is also crystallized in the hard casting, but the crystals are mixed together in every conceivable way.

29. Fig. 20 illustrates the arrangement of the crystals. The interior of an annealed piece always has some white spots, which look like flakes, radiating from the center. These are sometimes shrinkage spots, but are more often planes of separation due to the high contraction found in the white casting. In Fig. 21 these planes of separation are illustrated in exaggerated form. Fig. 21 (*b*) shows a section through *a b*, Fig. 21 (*a*), in the center of which the white spots are shown. A shrinkage spot is always spongy; sometimes the whole casting is one mass of spongy material with only the skin sound, and yet has a tensile strength equal to the best malleable iron. Close investigation will always show some small openings in the skin communicating with the spongy interior, which allow almost a complete decarbonization of this material. The casting then becomes a spongy piece of wrought iron or steel that bends well but will not resist shock.

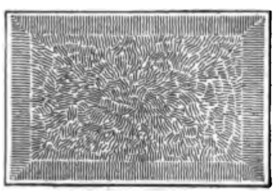


FIG. 20.

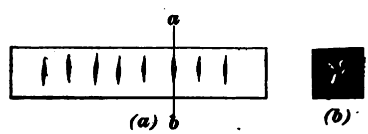


FIG. 21.

The introduction of steel into malleable mixtures changes the fracture considerably, the velvety black being changed to a granular dark gray structure showing a considerable

tearing apart of the crystals. Such a piece of malleable iron may be excellent.

A piece of malleable iron that shows a dull gray, often colored, and a banded structure, was nearly gray iron when it went into the annealing oven. This kind of metal is to be feared more than any other met with in the malleable-iron industry, as it is weak and worthless.

When the fractures are white, trouble may be experienced in locating the difficulty. If there are blowholes, the iron was low in silicon and burned in the furnace before it went to the annealing oven. Yet this iron if not too badly burned will be stronger than cast iron. If the structure resembles Fig. 20, the chances are that it is underannealed, and may be saved by returning it to the annealing oven. If, however, there are distinct flat crystals with shiny smooth faces, the iron was burned in the annealing oven and will remain worthless.

A casting is very often almost entirely white but has a black spot in the center; this is an indication of excessive annealing. If the white structure appears on one side only, the remainder being black, it is an indication that the iron is either very strong, or that too heavy a blow was struck in breaking off the test plug. Fig. 22 (*a*) shows a piece partially broken off, the blows being struck in the direction indicated by the arrow *a*. Breaking the piece off partially by repeated light blows, and then suddenly knocking it off will produce a white band, as shown in Fig. 22 (*b*), where the crystals did not have time to pull apart, but were suddenly snapped through in the middle. This often accounts for apparently bad test plugs when the iron is perfectly good.

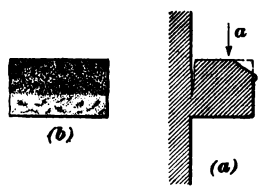


FIG. 22.

It is always advisable to preserve samples of bad work in order to study the effects of certain conditions, and as the workman gathers these specimens, which were made with the greatest care, he will get an insight into the peculiar

nature of malleable iron that will be of very great value to him.

30. Inspection and Storage of Castings.—When the castings are finished they are finally inspected, either by the makers or by the buyer's representative. When the dimensions of the castings must lie within certain limits, they are usually tested, by means of gauges and templets, in the chipping room where any needed correction can immediately be made. The castings now go either directly to the warehouse, or are covered with a coat of asphalt dissolved in benzine. In railroad work especially, such a coating is desirable, as it keeps the material reasonably free from rust until used. Care must be taken in storing the benzine as well as in using it, as it is extremely inflammable. The coating is put on with brushes and dries very quickly.

The warehouse should be so arranged that a stock of castings may be stored for a reasonable length of time. Some concerns make it a rule to keep in stock about 1,000 castings of each kind that is in constant demand, in order to be able to fill all orders promptly.

31. Annealed Test Pieces.—In the annealing room good hard castings may be spoiled. The annealer therefore has cast for his own use and guidance special test wedges about 1 inch square, and of the form shown in Fig. 23, on which are cast identification marks of the various heats. Thus a test piece annealed in furnace No. 8, the second heat, the first part, and which was cast on August 16, is marked as shown in the illustration.

FIG. 23.

These wedges are broken by the annealer to test their ductility. He then takes them to the superintendent's office, where they are arranged in cases properly dated. About 2 weeks' tests are generally kept on hand. An excellent guide whereby the working of the melting furnaces may be judged is thus furnished, defective iron being shown by a continued bad fracture.

SPECIAL ANNEALING EQUIPMENT.

32. Recent Developments in Annealing-Room Equipment.—Some of the most recent developments in annealing-oven construction present novel features. Instead of building the ovens above ground, and charging with trucks, they have in one instance been sunk below the floor level and the charging done with electric traveling cranes. There are no doors, the roofs of the ovens being removed in sections by the crane for the purpose of charging, and put on again in the same way when the charging is finished. The work of about 6 or 8 men is thus done by 1 man at the oven and a boy on the crane. The ovens are practically soaking pits; there is little loss of heat by radiation, there are very few buckstaves and tie-rods required, and the construction itself is very simple and inexpensive. No tiles need be used upon the floors, common No. 2 firebrick being sufficiently durable for this purpose, as there is no wear on them from a rolling truck. The flues in the bottom are arranged as in the ovens described, and the side walls are the same, but the end walls are carried higher to close up the ends of the

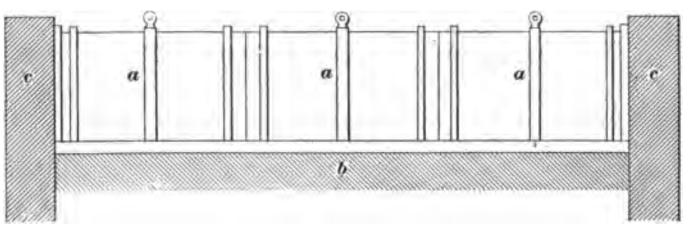


FIG. 24.

arched roof, as shown in Fig. 24, in which *a*, *a*, *a* are the sections of the roof, *b* the side walls, and *c*, *c* the end walls.

The roof, an end view of which is shown in Fig. 25, is the most important part of the oven construction. The sections consist of three deck beams *a*, Fig. 25, of a high type, bent in an arc of a circle and suitably connected together and attached to cast-iron heels *b*, *b*, so that a 9-inch brick arch, made of suitable arch brick, can be built within the structure

as shown. There are three of these sections in the roof; they are placed close together, and the spaces divided between the end section and the two end walls. The sections of the roof are made a little narrower than the space they are to occupy, thus making provision for expansion during the heating. The joints of the roof are all covered with fire-brick laid in mud, and as the ovens heat and expand, the joints must be watched and repaired, if necessary, to prevent

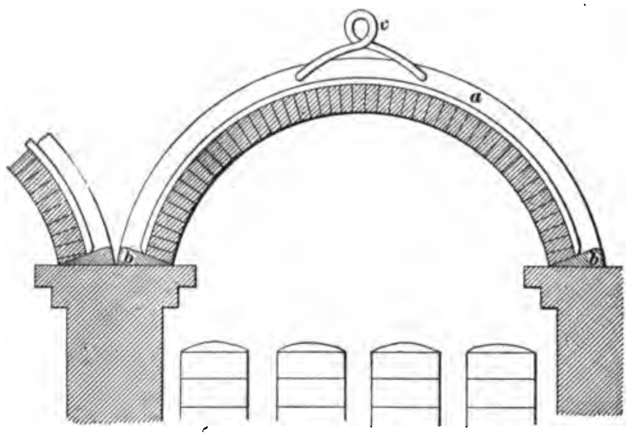


FIG. 25.

leakage. It will readily be seen that it is an easy matter to take the roof from one furnace while almost red hot and place it on another one that is just to be lighted. There is an appreciable saving made thereby in the time required for heating. When it is desired to move a section of the roof, the crane hook is simply caught into the eye *c* attached to the middle rail of the roof frame, and the section carried to the desired place. For the purpose of building and repairing these roof sections, a wooden form is kept in a suitable place, accessible to the crane, and the damaged sections placed on it for quick repair. Wells are provided on the outside of the oven large enough to permit a man to enter and control the dampers, and to make the temperature tests through the peep holes.

Forty of these ovens have been built in one set, two rows with twenty ovens in each being placed back to back. Two chimneys carry off the burned gases. Natural gas is used as a fuel, two sets of burners being placed above the pots and directly into the side walls, without fireboxes. The ovens have interior dimensions of 10 ft. × 20 ft. × 8 ft., being measured to the heel of the roof sections.

33. The traveling crane is kept in operation continually, day and night. The device used in lifting and carrying the pots by means of the traveling crane, called a *lifting frame*, is shown in Fig. 26. The crane hook is hooked in the eye a, and the two arms b, b, which are hinged at c, are lowered over the sides of the pot and under the projections on the ends of the stool. There are two of these, one with the distance between the arms a little greater than the length of the stool of the annealing pot and the other a little less. In charging an oven, the wider one is used, it being placed over the finished pot and the horizontal parts of the arms pushed toward each other until they catch securely under the edges of the stool and the pot lifted by means of the crane and carried over to the oven. The man in charge of the work in the meantime goes over to the oven to direct the lowering operation. When the pot is deposited in its proper place the lifting frame is lowered until the two arms are free to swing clear of the pot. The frame is then raised by means of the crane, and carried back for the next pot, taking the man with it. In discharging the oven, the other lifting frame is used. In dropping down over the pot, the arms must first be pushed apart a little. When they reach the bottom, they close automatically, catching the projecting lips of the stool, thus permitting the pot to be raised. It is understood, of course, that occasionally there will be some difficulty with a swelled or broken pot. In this case the lifting arms are taken off the cross-shaped frame d and chains substituted therefor. These are flexible

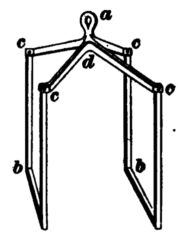


FIG. 26.

enough to adjust themselves properly under the stool and enable the whole mass to be raised. When the pots are still hot, an iron rod with a suitable handle will be of great assistance in guiding the lifting frame over the pot.

MISCELLANEOUS PROCESSES AND EQUIPMENT.

34. Reheating and the Reheating Furnace.—Some malleable castings of thin section and complicated form develop such intense internal strains upon cooling that they are liable to crack, if allowed to cool in the usual way. Such castings should be shaken out of the sand as soon as possible after pouring, allowing the sand to stick to them to prevent rapid cooling while exposed to the air. They should then while still red hot be placed in a reheating furnace, whose interior has been raised to a red heat before the molten metal is tapped from the malleable furnace. The castings should be kept hot for 2 or 3 hours, after which the furnace is allowed to cool down very slowly; when sufficiently cooled the castings and loose sand may be removed.

The furnace used for this purpose is very simple, consisting usually of a firebox running along the side of a hearth, on which the castings are placed, both the hearth and firebox being slightly raised from the ground. The fuel used may be oil, gas, coke, or coal. Coal will, however, require a longer time to heat the furnace than the other fuels.

Fig. 27 (*a*) and (*b*) shows a furnace constructed for the purpose of burning coke or coal, in which *a* is the firebox, *b* the hearth on which the castings are placed, *c* a low bridge wall, *d* the grate, *e* the ash-pit, *f* the fire-door, *g* the charging door, and *h* the chimney flue. Fig. 27 (*b*) shows a section on the line *x y*, Fig. 27 (*a*). The grate *d* is placed sufficiently below the hearth to give the required depth of the fuel bed; the bridge wall *c* is made high enough to prevent the

castings from rolling into the fire, and the chimney flue *h* is raised somewhat above the level of the hearth to prevent the loose sand from choking up the flue. A damper should

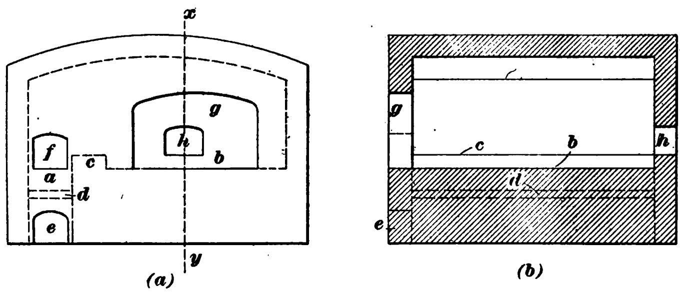


FIG. 27.

be used in the chimney flue, so that it may be closed in order to retain the heat in the furnace and allow it to cool very slowly.

This form of furnace is also sometimes used to heat castings that have become warped in the annealing process and cannot be straightened cold. Very great care must, however, be taken when this is done to prevent the temperature from becoming excessively high, as this tends to destroy the strength of annealed castings and renders them hard to machine.

35. Special Annealing Processes.—In one well-known foundry that makes malleable pipe fittings, the hard castings are simply thrown into the oven and annealed without any packing whatever. The temperature is kept high, but the process is necessarily short, as the castings heat up quickly and are of such a nature that they do not warp during the process. Subsequent rolling in a long inclined tumbling barrel produces a good finish. The process while good for this class of work is not to be recommended generally.

In another foundry the ovens and the pots are made large, and in order to obtain a quick penetration of the annealing heat, pieces of pipe, which extend through the stool and

cover, are inserted in the pots, thus creating a circulation of the hot gases not otherwise obtainable. This method is very desirable for large, flat castings of favorable design.

Another method of annealing is practiced in one of the large works of this country. The ovens are made very narrow and the castings packed in them in scale, without the use of pots. This method has its advantages and disadvantages. There is danger of imperfect heating and annealing, and when overheated the castings are liable to be warped out of shape. It should therefore be used only for heavy castings that are not liable to be warped in the annealing process. The capacity of the oven also is limited and the amount of fuel used excessive. On the other hand, the great expense of annealing pots is entirely avoided.

36. Firing.—In annealing as well as melting practice, the chimney is a good guide as to what is going on in the furnaces. It is a common error of melters and annealers to use too much fuel in the desire to get up a good heat. Instead of forcing the fires by using too much coal or gas, it is better to use less fuel, but burn it completely. When the smoke that leaves the chimney is darker than a light brown, it indicates that the combustion is incomplete and gas or coal is burned uselessly. The only exceptions to this rule are at the moment when the direction of air and gas is reversed in the open-hearth furnace, and in starting up of an annealing oven. The superintendent, foreman, melters, and heaters should constantly watch the chimneys for indications of incomplete combustion.

37. Galvanizing.—Certain classes of malleable castings, as pipe fittings, for instance, are frequently galvanized. This process reduces the strength of the iron considerably, and it should therefore be used only when the protection of the surface from corrosion is more important than the strength of the iron. The process of galvanizing malleable iron is the same as that used in galvanizing ordinary gray iron.

BRASS FOUNDING.

MAKING BRASS CASTINGS.

MOLD MAKING.

INTRODUCTION.

1. Iron and Brass Molds Compared.—The making of molds for **brass castings** is so similar in principle and practice to the making of molds for iron castings that he who understands making them for iron can readily learn to make them for brass; and, in some kinds of brass work, the iron molder may be more successful than the regular brass molder.

Molds for small brass castings are made on benches or over troughs, or on molding machines, while heavy castings are made on the floor, as is done with corresponding sizes of iron castings. The principal difference between molds for brass and for iron is that the brass-work molds are made from finer grades of sand. The lighter and finer the castings to be made, the finer must be the grade of sand used in the molds. If the sand is too coarse, the melted brass is sufficiently fluid to find its way into the openings among the grains, making the surface of the casting rough and pitted; hence, it is advisable to use the finest grade of sand that the character of the casting will permit. In addition to finer and cleaner sand, brass molding requires a greater allowance for contraction, different facings, parting sand, and finishings, and about the same blackening mixtures and methods of drying and ventilating as in iron molding.

Bronze, fine art, statue founding, etc. is a specific trade in itself, and is not within the province of the brass molder, as outlined in this Section.

MATERIALS USED IN BRASS MOLDING.

2. Sand for Brass Work.—Where light castings are made only occasionally and are not a regular output of the shop, the molds for them may be made in the following manner: The coarser sand ordinarily used in iron molding is dried thoroughly and then sifted through a fine sieve, the portion that does not pass through being cast away. The portion that does pass through is then tempered, and used to face the mold by being sifted over the pattern; the remainder of the mold may be made from the sand ordinarily used.

It is important to have the molding sand as free from all foreign material as is possible, for anything that will coarsen the sand will tend to give a rough surface to the casting. Brass founders are very particular in this respect, and pieces of cores that may break off are carefully picked out of the molding sand; some founders even avoid the use of the regular parting sand, and use in its stead powdered rosin, or a mixture of rosin and charcoal, on the joints of the molds.

If the form of the casting is so intricate as to make it inadvisable to take the risk of the green sand supporting itself in the more delicate parts, or if the mold is so deep that the green sand will not support itself at the bottom, it may be necessary to use a dry-sand mold or a loam mold.

The sand mixtures for dry-sand or loam work should be close-grained, but of such a character as not to bake too hard, as this will cause the metal to boil when the mold is poured; besides, the metal will not stay in contact with the sides of the mold, so that a bad casting will result.

3. Blackenings and Partings for Brass Molds. The methods and mixtures used for blackening the surfaces of dry-sand and loam molds for iron may be used for brass

molding. In some cases skin drying is practiced for brass as well as for iron. The principal difference is that instead of using ordinary blackenings, and sleeking and printing the molds, as in iron work, other substances, such as flour, whiting, lime, water-lime cement, powdered chalk, and lycopode, are used. Plumbago is used for heavy brasses, especially those of red or whitish color, but is objectionable for yellow brass. Whichever one of these substances is used, it should be ground fine, so as to close up the pores of the sand as much as possible in order to prevent the metal cutting into the sand and giving a rough casting. For heavy work, flour is shaken out of a bag on the mold surface, and then plumbago thrown by hand or shaken out of a bag on top of the flour, after which the surface is sleeked with finishing tools similar to those used in finishing dry blackening on iron molds. Where the molds are liable to stand for more than 10 hours before being poured, flour is objectionable for the reason that it causes a vegetable growth on the face of the mold that may cause rough castings; it also causes the parts of the joint to stick together.

The joints in the molds are made by match boards, plates, sand odd-sides, or composition matches, as in the molds for iron; but great care must be used in the selection of a parting sand to find a material that will not coarsen the regular molding sand when mixed with it, since the ordinary parting sand will give trouble in this respect.

For a parting material at the joints, powdered rosin, or a mixture of powdered rosin and charcoal dust, is often used. A material lately introduced for this purpose, called **lycopode,** is said to work well, and besides makes a good facing for preventing the adhesion of the sand to the pattern. Much trouble is experienced at times by sand adhering to the surfaces of metal patterns, especially in damp or frosty weather, when the moisture in the air condenses on the metallic surfaces. The molders then say that the patterns are **sweating.** Some molders brush kerosene oil over the surfaces in order to prevent this adhesion, but this plan is not entirely satisfactory.

MAKING MOLDS FOR BRASS CASTINGS.

4. Mixing Facings for Molds.—In mixing facings for brass castings, sea coal or coke is not required, as is the case with iron castings. New molding sand that has been carefully screened and mixed to an even temper is generally used. This is applied to the face of the pattern through a fine sieve. In tempering, the same principles hold as with sand used for iron castings; the sand should be thoroughly mixed. The drier it is when placed in the mold, the better; since an excess of moisture will make steam, and thus cause scabs and blowing, in the same manner as occurs when pouring iron castings. The molds are rammed to about the same degree of firmness in both cases.

5. Venting Molds.—The methods of venting are, in general, the same for brass work as for iron, though the cope should be vented more freely in the former case, so as to allow an easy escape of the enclosed air and gases during the pouring, thus allowing the metal to run quickly and solidly into the corners. Small vent holes are often made entirely through the cope for this purpose.

6. Drying Molds.—Sometimes small molds are dried by burning gasoline on their surfaces; at other times they are covered with a red-hot plate until the heat gives the surface a hard, dry crust. Some molders dry the surface of a mold by holding it over a burning lamp, which also serves the purpose of smoking it. The same object may also be accomplished by holding the mold over a piece of burning rosin. The mold may be dried by placing a burning gas jet inside, and then covering it over with a plate. With some sands it is necessary to spray the surface with molasses water to obtain the necessary hardness on the surface.

7. Provision for Contraction.—The **contraction** that occurs in a brass casting during cooling exceeds that of an iron casting. Where the contraction in iron is $\frac{1}{8}$ inch to the foot, that in brass is $\frac{3}{16}$ inch; since the contraction is

fairly uniform, it may be provided for in making the pattern. If metal patterns for brass are to be made from wooden ones, the shrinkage allowance in the wood patterns should be double the usual allowance.

In dry-sand or loam molding, provision should be made for contraction while the casting is cooling. In many cases, if this provision is not made, the casting will break. This is especially likely to occur where the brass contains a large percentage of copper. If the core in a mold is made in such a way that the casting as it contracts in cooling cannot crush it, or if the core rods running from one side of the core to the other are too near the surface and will not give way, the casting is likely to break. In order to prevent this, the cores should always be made in such a manner that they will yield when the casting contracts; for this purpose they may be filled with cinders, or they may be made of some yielding material. This advice is applicable to both dry-sand molds and green-sand molds.

8. Gating and Feeding Molds.—Owing to the fact that brass, if it drops any considerable distance, will cut the sand in a mold, and thus cause lumps or scabs on a casting, it is usually better to *gate* a mold for a heavy casting as near the bottom as possible. If the casting is deep, it may have top-pouring gates in connection with the bottom gate.

With light castings, the danger of cutting the mold and of scabbing is not so serious; but the question of shaping the gates properly, and of so placing them that the casting will be full and sharp at the corners, is important. In order to aid the metal in filling the mold properly, the mold is often placed in an inclined position, with the pouring gate *a* at the top, as shown in Fig. 1.

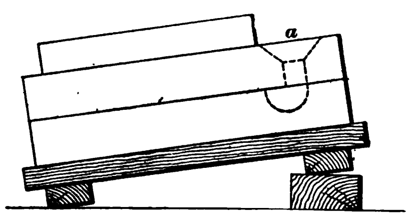


FIG. 1.

Where the castings are of a bulky character, provision is generally made to prevent shrinkage; for this purpose *feeders* are brought to the heavier parts. In constructing these feeders, it is better to connect them with the upper edge, as shown by the feeder *c*, Fig. 2, than to place them directly on the top face of the casting, as shown by the feeder *b*. After the mold has been poured, it should be fed occasionally from the crucible as long as the metal remains fluid. This is determined by the metal in the feeding heads rising when fresh metal is poured into the gates or feeding heads.

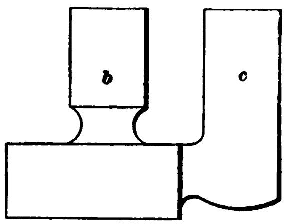


FIG. 2.

A wooden feeding rod may be used in pouring brass molds, instead of a metal rod, as used in iron molding. The wood should be thoroughly dried.

The feeders and their connections should be large enough to remain fluid as long as the casting does; this necessity exists as much in brass casting as in iron casting.

CLEANING BRASS CASTINGS.

9. Hand Work.—Usually the sand is removed from brass castings by means of wire brushes and files. The gates and feeders are removed by making cuts with hack saws and chisels to a depth sufficient to allow these parts to be broken off with a hammer. After the gates and feeders have been removed, any projections that they leave are cut off with chisels or files, or by grinding. When files are used, they must be cleaned occasionally with a file card. The sand blast, sprue, or gate-cutting machines, and several other labor-saving devices are also employed for cleaning castings. There are in the market several forms of sprue-cutting or gate-cutting machines, as well as power band saws for cutting off gates.

10. Tumbling barrels used for cleaning brass castings are made with wooden staves, to avoid breaking the corners of the castings, and also are often arranged to hold water. When being charged, the tumbling barrel should be nearly filled, so that the castings may not tumble about too much and thus bruise their corners; small scraps and floor shot should be packed in with the charge, as they assist in cleaning the castings.

11. Pickling.—Brass castings are **pickled** in nearly the same manner as iron castings. A *pickling liquor* that is sometimes used consists of 2 parts, by measure, of nitric acid and 3 parts of sulphuric acid, with a handful of table salt to each quart, no water being added. The pickle may be held in any suitable receptacle, such as a glazed earthenware crock, or a vitrified bathtub; it is necessary to provide a vessel large enough to hold the largest casting to be handled. The castings are simply dipped and removed at once and rinsed in clear water. This dip is merely for cleaning and brightening the castings. Various dips are used to produce different colors.

APPLIANCES FOR MELTING BRASS.

THE CRUCIBLE FURNACE.

12. Introduction.—The **furnaces** for brass melting may vary from a plain pipe stuck into the ground and supplied with a bottom grate and a stack to the most elaborate devices. Some brass founders use air furnaces, while others use cupola furnaces, but the **crucible furnace** is the most common. The plain cylinder furnace with a grate and stack that can be worked by natural draft, or, with the stack omitted, by forced draft, is also used. Some patent furnaces for which many advantages are claimed are also in use.

13. Location of Brass Furnace.—The furnace for melting brass is usually built in a corner of the shop, if it has only a single firebox; but if there are several furnaces built in a battery, they are placed alongside the wall where the flues can be connected with an outside chimney or stack. They may be arranged to have the ash-pit either inside or outside the shop walls. If the pit is on the inside, it is usually covered with grated plates and has the opening on a level with the floor surface; or it may be built above the floor level and have a grated front for the admission of air. In some brass foundries the furnaces are located in the center of the building, where they are easy of access.

14. Simple Brass Furnace.—The construction of a **simple furnace** for melting brass is shown in Fig. 3. It

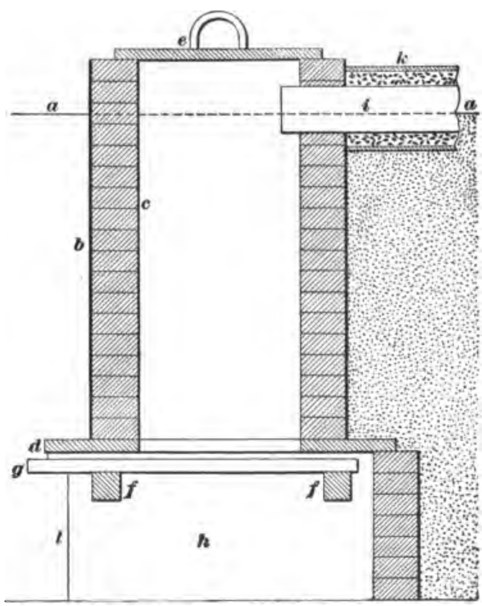


FIG. 3.

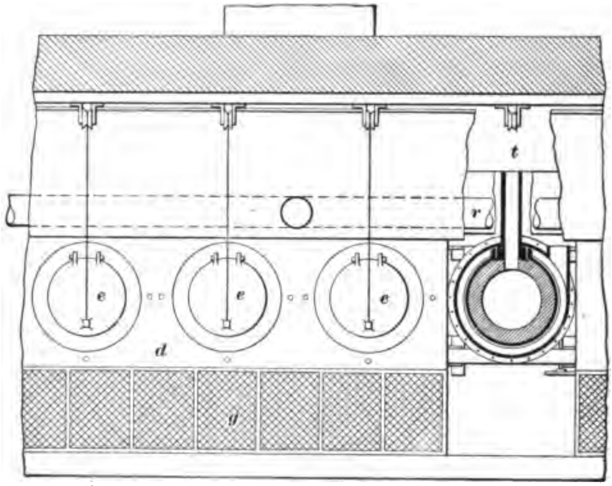
is built below the floor level *a* and consists of a sheet-iron shell *b* lined with firebricks *c*, resting on a bedplate *d*, and

fitted with a cast-iron cover *e*. The covers are usually provided with a refractory lining. Two bearing bars *f*, *f* support the loose grate bars *g*. The ash-pit *h* is usually from 12 to 18 inches deep. The products of combustion pass through a flue *i* near the floor line *a*.

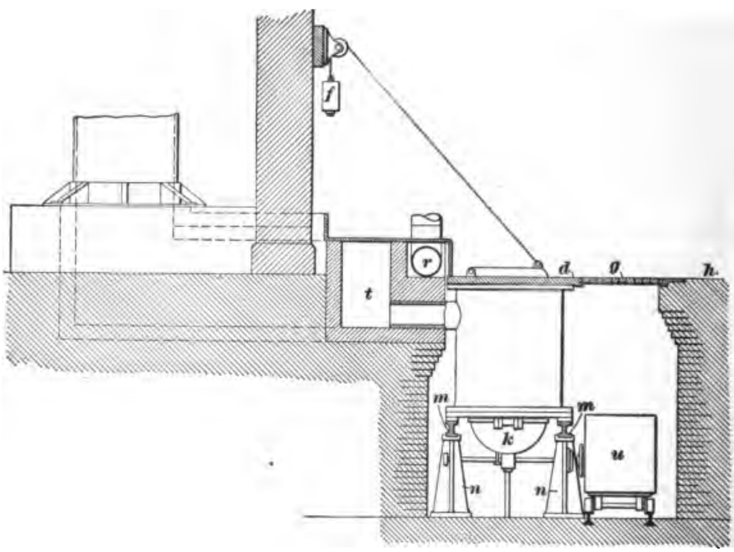
The flue should have a diameter equal to about one-third that of the furnace and be connected to a chimney or flue that has an area at least as great as its own, and which is high enough to give a good draft. The height of the chimney will depend to a great extent on the surroundings. The flue *i* should be lined with firebrick or fireclay to protect the shell *k*; some founders use a cast-iron pipe, however, for a flue and renew it whenever it is burned away. The top of the furnace is generally made from 6 to 12 inches above the level of the floor line *a*. The inside diameter of the lining is generally made from 6 to 8 inches larger than the greatest diameter of the largest crucible that will be used. The furnace is usually made of such a height that the top of the crucible will be within 3 inches of the bottom of the flue *i* when there is about 9 inches of fuel under the crucible.

The grate bars *g* have a considerable influence on the character of the draft. They may be plain, straight, cast-iron, or wrought-iron bars; or the grate may be one circular casting. If made of separately cast bars, it is well to have lugs cast near their ends, to keep them at a uniform distance from one another, since this allows a uniform draft to pass through the fire, and gives better combustion in the furnace.

15. Brass Furnaces in a Battery.—Where more than one crucible furnace is required, and where they can be connected together, all the flues may lead to one main flue that connects with a chimney placed midway between the furnaces; for, if the chimney is at one end of the row, the furnace that is farthest away may suffer for lack of draft. The main flue should have an area equal to the combined area of the flues that form the branches. Where natural



(a)



(b)

FIG. 4.

draft is depended on, every care should be taken to have it as good as is possible under the existing conditions; for, if the draft is light, the speed of melting will be low and the quality of the metal poor.

An improved furnace that is used in the brass foundry of one of the largest railways in the United States is shown in Figs. 4 (*a*) and (*b*), and 5 (*a*) and (*b*). Fig. 4 (*b*) shows the end elevation, and (*a*) a plan with sections of a battery of four furnaces. The furnace consists of two cast-iron

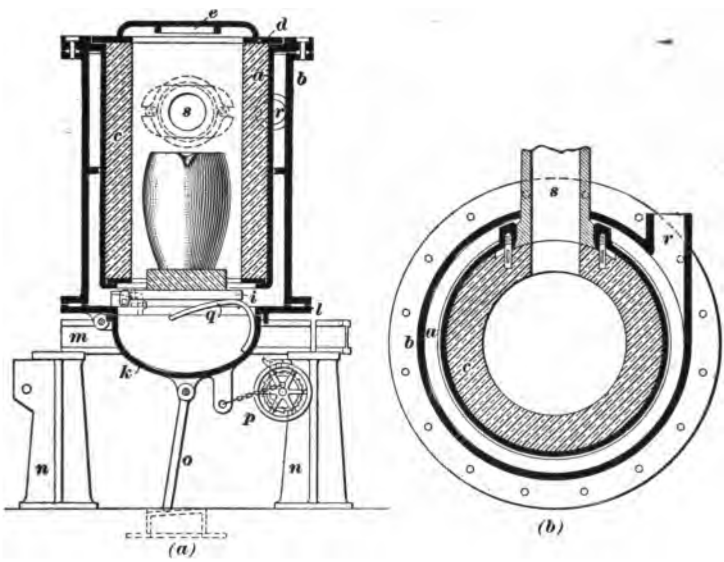


FIG. 5.

cylinders *a*, *b*, Fig. 5 (*a*) and (*b*), one within the other with an air space between. The inner one is lined with firebrick *c* and has a square top cover *d*, Fig. 4 (*a*), with a circular door *e*, which is counterbalanced by means of a chain and weight *f*, Fig. 4 (*b*). The covers *d* of the furnaces with the gratings *g* over the ash-pit make a continuous platform on the floor level *h*, as shown in Fig. 4 (*b*). A hinged grate *i* forms the bottom of the inner cylinder and a spherical door *k* hinged to the circular bottom casting *l* closes the bottom

of the outer one, as shown in Fig. 5 (*a*). The whole furnace is supported by **I** beams *m*, *m* on posts *n* resting on foundations below the level of the ash-pit floor, as shown in Fig. 4 (*b*). The lower door *k* is held securely in a closed position by a hinged prop *o* and is opened and closed by means of a chain wound on the shaft of a hand wheel *p*, and a ratchet and pawl, as shown in Fig. 5 (*a*). The bottom *k* is made bowl-shaped so as to serve as an ash receiver and also large enough to hold the metal if a crucible should break. A heavy curved piece of iron *q* fastened to the inside of the bowl lifts and holds the grate *i* in position. The blast from the blower enters at *r* and the burned gases pass through the upper opening *s* to the stack, as shown in Fig. 5 (*b*). The blast pipes *r* are laid along the escape flues *t*, Fig. 4 (*a*) and (*b*), and the air flows through the heated space between the cylinders *a*, *b*, as shown in Fig. 5 (*a*) and (*b*). This plan utilizes considerable waste heat and greatly reduces the time necessary to melt the charge. An ash-car *u* runs on tracks in the pit and is lifted from the pit by means of a pneumatic hoist operating on an overhead trolley; the hoist also serves to handle the crucibles, which are No. 80 in size and rest directly upon the grate *i*. In many cases chain hoists are used for handling the crucibles.

16. Increasing the Speed of Melting Brass.—It is at times desirable to increase the speed of melting in the regular crucible furnace. This may be done by inserting a blast pipe from a blower, under the grate, and closing the front of the ash-pit with a piece of sheet iron *l*, as shown in Fig. 3. Where 2 hours are required to melt the metal under natural draft, 1 hour will generally suffice with forced draft; but the forced draft is much harder on the crucibles, and, besides, requires constant attendance from the founder. Nevertheless, there may be times when the high speed of melting is desirable.

17. Combined Cupola and Crucible Furnace.—In Fig. 6 is shown a sectional view of a furnace arranged with

a sand bottom, so that the metal may be melted in direct contact with the fuel; or, by replacing the sand bottom with a grate, the metal may be melted in crucibles. When using this furnace without a grate for melting copper, it is necessary to have the blast much milder than when melting iron, and to use from one-eighth to one-fourth more fuel. In preparing the furnace, the daubing should be put on thinly and the surface should be blackened over, as in blackening a dry-sand core or dry-sand mold, for the cleaner the metal is kept in melting it, the better will be the results in casting. Only the copper should be melted in this cupola, and the tin and zinc for the mixture should be added to the copper after it has been tapped from the cupola; or the other components of the desired alloy may be in the ladle in a melted state when the copper is drawn from the cupola. Mixing the alloy while it is in direct contact with the fuel causes it to absorb sulphur from the fuel, and metallic oxides are formed, which, with the sulphur, may generate gases and so cause blowholes in the castings. Many founders who have tried to melt brass in a cupola have experienced this trouble.

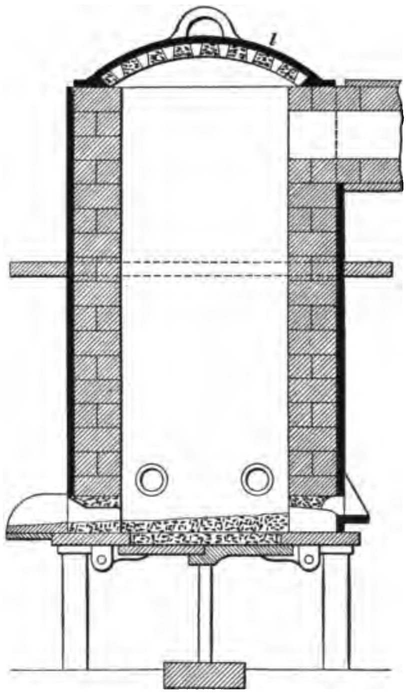


FIG. 6.

When crucibles are used in the furnace shown in Fig. 6, they should be charged in the same manner as in the regular crucible furnace. They should be set in the cupola on a bed

of fuel ranging from 8 to 10 inches in depth; fuel should be placed around their sides and the blast applied, instead of using the natural draft.

18. Oil-Burning Brass Furnace.—While the crucible method is the most common one for melting brass, it is also melted in contact with the flame in furnaces that use crude petroleum for fuel. In Fig. 7 is shown one form of oil-burning furnace. It consists of a pear-shaped boiler-plate shell *a* mounted on trunnions *b*, *b′* supported by stand-

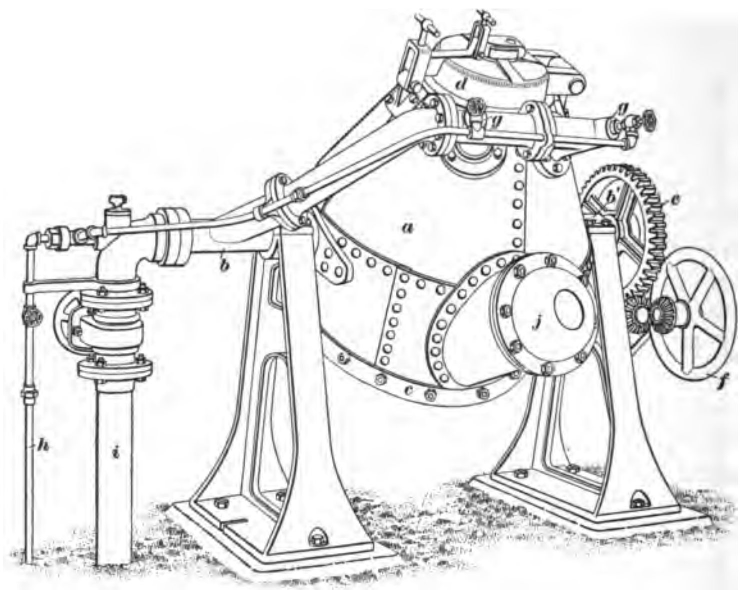


FIG. 7.

ards on substantial foundations. The bottom *c* is removable for the purpose of lining the shell *a* with firebricks, making repairs, etc. After the bottom *c* is bolted in place, the materials for its lining are introduced through the hinged charging door *d* at the top of the furnace. The furnace is tilted and held in any desired position by means of a worm-wheel *e* on the trunnion *b′* and a worm and bevel gears

operated by a hand wheel *f*. The air and oil enter the furnace near the top through two tuyeres *g*, *g* placed at an angle to each other and pointing downwards. The oil pipe *h* and the air pipe *i* are connected to the movable parts on the furnace by means of stuffingboxes at the end of the trunnion *b*. The furnace is heated to its working temperature before the charge is put in. To aid in preventing excessive oxidation of the charge, it is necessary to cover it with some material to protect it; a small amount of fine anthracite coal is sometimes used for this purpose. When the charge is melted, it is emptied into ladles through the brick-lined spout *j*, which is also the only outlet for the products of combustion; the operation of the furnace is judged by observing the flame that issues from the spout. The advantages of this furnace are that a larger amount of metal can be melted in one bath than where crucibles are used, and a greater amount of metal can be melted in a given time per square foot of floor space occupied by the furnace.

CRUCIBLES FOR MELTING BRASS.

19. Care of Crucibles.—If the crucibles used in melting brass be handled carefully, they will last thirty or more heats; but if they are handled carelessly or ignorantly, they may be injured by crushing or cracking in one or two heats.

The first thing necessary to the life of a crucible is that it be annealed thoroughly for several days at a moderate heat, ranging about 220° F., such as the mild heat in core ovens. Crucibles are usually thoroughly annealed when being made, but in transportation from the maker to the user, they absorb moisture that must be slowly driven out or they will crack at the first heat.

In the case of large crucibles, it is well, after annealing them in an oven, to keep them mouth downwards over a slow fire for 6 or 8 hours.

A sufficient number of crucibles should be kept on hand, so that any of them that are partly glazed may be saved for

heavy heats or any especially hot firing that may be on hand.

A crucible used where the melting is done in from $1\frac{1}{2}$ hours to $1\frac{3}{4}$ hours, under forced draft, cannot last as long as one where from 2 to 4 hours are taken in the melting. The character of fuel used may also have much to do with the life of a crucible. If the draft or damper is regulated in such a manner as to produce an oxidizing instead of a reducing flame, the effect will prove injurious to the life of the crucible.

The kinds of metals melted also are important factors. A crucible that will last only three heats when melting nickel may last six heats with steel, twenty-five heats with copper, and possibly the same pot may be used forty times when melting the soft compositions.

In charging furnaces, the metal should not be jammed into the crucible, as this will strain the pot and cause slight cracks. In using the tongs, they should be made to fit the crucible closely, since if they do not fit, they will strain the parts with which they are in contact.

After pouring the metal out of the crucible, care should be taken to see that none remains in the bottom, as it will adhere to the bottom and tear it when it has cooled, or while being removed when the crucible is being prepared for the next heat.

When the heat is finished, the crucible should be stored away in some warm, dry place until the next heat; and if this interval lasts more than a few days, it should be put in the core oven and heated before being used again.

In ordering crucibles, it is well to inform the manufacturer of the kind of metal for which it will be used; this will enable him to select a mixture for the crucible that will be suitable for the intended work.

20. Capacities of Crucibles.—Table I gives the diameter of crucibles and the pounds of metal they will hold, as well as the numbers by which they are sold by dealers.

TABLE I.

SIZE AND CAPACITY OF CRUCIBLES.

Number of Crucible.	Outside Height. Inches.	Greatest Outside Diameter. Inches.	Capacity in Melted Metal. Pounds.
1	3½	3	3
2	4	3¼	6
3	4⅝	3¾	9
4	5⅛	4¼	12
5	6	4⅝	15
6	6½	5⅛	18
8	7¼	5⅞	24
10	8¼	6¼	30
12	8⅝	6½	36
14	9⅛	7¼	42
16	9⅝	7¾	48
18	10	8⅛	54
20	10⅝	8⅝	60
25	11⅛	9	75
30	11¾	9⅜	90
35	12¼	9¾	105
40	12⅝	9⅞	120
45	13	10½	135
50	13¾	10¾	150
60	14⅛	11¼	180
70	14¾	11¾	210
80	15½	12½	240
100	16⅛	13	300

MELTING COPPER AND OLD BRASS.

21. Operating the Brass Furnace.—Before placing the crucible in the furnace, the fire should be well under way; there should be sufficient fuel in the furnace to form

a solid bed from 8 to 10 inches thick between the grate and the crucible, which should be charged with the metal before it is placed on the bed of burning fuel. The crucible is packed closely, and is filled to the top, the metal being allowed to protrude from the top, if it is known that when melted it will not quite fill the crucible. The crucible tongs, one form of which is shown in Fig. 8, are then placed over the crucible, and are held in place by means of the link *a*. The crucible is then lifted and lowered into the furnace by the tongs and set evenly on the bed of fuel. The tongs are now removed, and fuel, broken to a medium size, is shoveled into the furnace to fill the space between the crucible and the sides of the furnace, the fuel being filled in to the level of the top of the crucible.

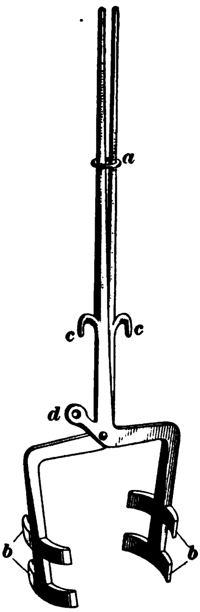


FIG. 8.

22. Adjusting the Crucible.—As the fuel burns away, the crucible will settle gradually toward the grate, and to prevent its settling too low, so that there will not be a sufficient body of fire under it, it is raised occasionally by means of the crucible tongs to its original position. When the crucible is raised, the fuel from the sides settles down under it, and the crucible is readjusted on the bed; the crucible tongs are then removed and fresh fuel added to replace that which has settled under the crucible. The cover *l*, Figs. 3 and 6, is put in place in order to continue the draft and keep the heat in the furnace.

In some cases the crucible may need adjusting in this way two or three times before the metal will be hot enough to be poured into the molds. As the furnace cools somewhat every time it is opened for the admission of fresh fuel, the fire should be so arranged that it will not need fuel just before the metal is poured, for renewing it at that time will

cause a setback by cooling the metal. Usually the crucible will take more metal when the first charge melts and settles, in which case the additional metal is gently added by means

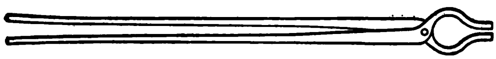


FIG. 9.

of the tongs shown in Fig. 9. This method of melting brings the whole potful to the melting temperature in a uniform manner.

The metal should not be left in the furnace longer than is necessary to give it the degree of fluidity necessary to pour it, for if the temperature is increased beyond this point, it will cause injury to the metal and may cause blowholes in the castings, especially if the metal has a large percentage of copper. The proper temperature can be determined only by watching the alloy closely during the melting. If, when a rod is inserted into the molten metal, no metal adheres when it is withdrawn, the metal is at least warm enough to be poured. If it is held in the fire longer, it will be injured by absorbing oxygen from the air. If old brass is used, some of the zinc will oxidize, or burn out; this loss must be replaced by new material.

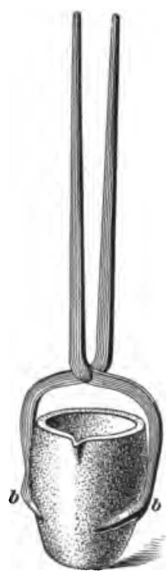


FIG. 10.

23. Handling the Crucible and Metal.—When taking the crucible out of the furnace with the tongs, care must be taken that the jaws *b*, *b*, Figs. 8 and 10, of the tongs are below the largest part of the crucible, as is shown in Fig. 10, for if they are not, the pot may slip out of the tongs before it reaches the top of the furnace or as it is being carried around the floor, thus spilling and losing the metal and endangering the workmen. When the tongs clasp the pot, a link *a*, Fig. 8, is slid along the handles, as shown, and made

to press them tightly together; the pot can then be lifted out of the furnace. If the pot is too heavy for one man to handle, it is lifted by two or more men taking hold of the handles and lifting it to the top of the furnace. When the crucible is very heavy, a chain hoist is used, hooking it on one of the hooks *c*, or attaching it to the eye *d*, Fig. 8.

Sometimes the hoists are suspended from overhead rails or trolleyways that permit of the crucible being carried from the furnace to the mold while it is suspended in the

FIG. 11.

lifting tongs; or it may be lowered into a ladle shank *a*, as shown in Fig. 11. In pouring by the use of these shanks, an extra helper is required to hold the crucible in the shank.

24. Oxidation in Melting Brass.—As the melting proceeds in the furnace, care should be taken to keep the top of the molten metal from contact with the air as much as possible. This is done by covering the metal with powdered charcoal, glass, or some other fine, dry dust. Copper, especially, has an affinity for oxygen, and care must be taken to prevent its absorbing oxygen from the air, since this affects the strength and homogeneity of the castings to such an extent that when they are broken oxide spots will be found in addition to blowholes. To prevent this as much as possible, many founders will not remove the covering of charcoal, or whatever covering may be used, from the surface of the metal until the last moment before pouring, and may even leave it on during the pouring, holding it back with a skimmer.

The evil of **oxidation** is so serious with nearly pure copper and some kinds of bronze castings that the scheme of using secondary ladles that permit bottom pouring is sometimes used. These secondary ladles have a hole through the bottom that is from 1 inch to $1\frac{1}{4}$ inches in diameter, according to the speed of pouring desired. The hole is stopped with an iron plug that is coated with clay or graphite, and which is so arranged that it can be pulled out when desired, thus permitting the flow of the metal through the bottom of the ladle. This bottom hole should be connected as closely as possible with the pouring gate of the mold, for if this is not done, the metal may be sufficiently exposed to the air in its passage to the gate to absorb as much oxygen as though no secondary pot had been used. Even with such a device closely connected to the pouring gate, it is impossible to prevent copper and some bronzes from absorbing some oxygen from the air in the mold. While it is true that this device does not wholly prevent the absorption of oxygen, there are times when its use will produce results that will justify its adoption.

25. Precautions in Melting Brass.—The best fuels for melting copper are charcoal and coke, the former being given the preference when the best results are desired. In melting the copper, care should be taken not to raise the temperature any higher than is necessary; this may be determined by the metals with which it is alloyed, or it may be determined by running the molten metal into the thin portions and corners of the castings. The higher the temperature is raised when melting, the more oxide and gases will be formed; if the temperature be great enough to obtain a white, or boiling, heat, it may be impossible to produce sound castings, and, in addition, the castings will be very brittle. When molten copper has been overheated, it may be brought again to a proper condition by adding tin or phosphorus to it. The greater the amount of phosphorus or tin that is added, the more sound are the castings likely to be.

26. Buying Copper.—Copper, like pig iron, should be bought on analysis, so that its constituents may be known to the desired degree of accuracy. It can be purchased on a guarantee that it contains 99.6 per cent. pure copper and is entirely free from sulphur. If it comes in ingot form, the manufacturer's name should be cast on each ingot. The ingot should have a concave face on the side that was cast uppermost, as this shows the amount of shrinkage likely to occur from its use. In obtaining an analysis of a shipment of copper, drillings are taken from ingots selected from equal divisions of the shipment, after the manner used in obtaining analyses of iron.

DEOXIDIZING METALS.

27. Silicon.—It is beneficial to both the strength and homogeneity of copper, brass, and bronze castings to remove as much of the oxides or occluded gases arising from the absorption of oxygen as is possible. For this purpose an alloy of copper that contains from 3 to 5 parts of silicon and from 90 to 95 parts of copper is often used. The usefulness of this mixture is due to the oxygen having a greater affinity for the silicon than for the copper; hence the oxygen in the metal unites with the silicon and forms a silicate that rises to the surface and can be skimmed off. The addition of from 1 pound to 1½ pounds of this alloy to 100 pounds of copper is said to produce sound copper castings; if this is not done, the founder may often experience much trouble from blowholes, which are due to the occluded gases.

In adding silicon care must be taken to add it in such small quantities that none will be left after the oxides are fluxed off. When added to the molten metal, the mass should be well stirred with a rod in order to bring as much as possible of the copper in contact with the flux. This is practically a refining process.

28. Stirring the Copper. — One method for deoxidizing melted copper is to stir the copper slowly and steadily

with a stick of unseasoned hard wood, from 1½ to 2 inches thick, until a sample of the copper will show, on cooling, a small shrink hole of a brownish color in its center; the stirring is then continued (taking care not to allow the temperature of the metal to rise) for a few minutes until a sample taken will cool with a level surface, without showing either any shrink hole or any elevation in the center; the metal is then ready to be poured. Should the stirring be continued much longer, the metal will revert to its former condition because of the occluded gases. While the metal is being stirred, it should be kept covered with powdered charcoal, or some other means, to keep it from contact with the air. This plan has resulted in obtaining solid castings from pure copper.

29. Phosphorus is also introduced into the metal as a deoxidizing agent; it is beneficial, since the oxygen will combine with it and pass off as an oxide of phosphorus in the form of a yellowish-white smoke. Phosphorus may be obtained from druggists in the form of sticks about the size of a finger, which weigh about 2 ounces each. A half dozen or more are put up in a can or bottle that is then filled with water and sealed or stoppered, since the phosphorus will ignite at 111° F. and will take fire of its own accord if left exposed to the air.

As the phosphorus will take fire in a few seconds in the hand, if it were removed from the water in that way, thus causing a painful burn, means must be provided for immersing it in the molten metal. One way to accomplish this is to insert the phosphorus in a tube made of clay or graphite, having a ⅞-inch hole extending through it. This tube is attached to the end of a metal rod, and the sticks of phosphorus are held in the tube by means of some strips of tin or copper that are fastened over the end. The tube is immersed in the molten metal and held there until the phosphorus is absorbed.

Another plan is to use an iron receptacle *a*, shown in Fig. 12, with a handle *b*. Several sticks of phosphorus are

inserted into the chamber *c*, and kept there until they are dry and show signs of catching fire, after which the holder is tilted gently and lowered into the molten metal, where it is held until the phosphorus has been absorbed.

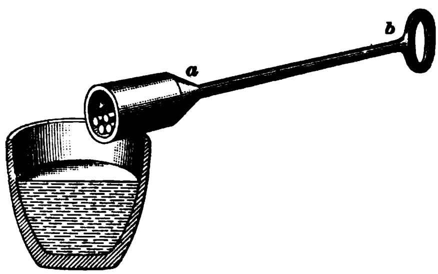


FIG. 12.

In order that the phosphorus may be safely handled and inserted in the molten metal, some founders prepare it by placing the sticks in a dilute solution of sulphate of copper for about 30 minutes. This deposits a coating of copper on the sticks, when they may be safely handled as long as this coating is sound. The sulphate-of-copper solution may be held in a stone jar, and when the sticks are taken out they may be placed on blotting paper that rests on wire netting, the netting being supported in a pan that is about 6 inches deep and contains about 2 inches of water. The pan should be provided with an air-tight cover, to be used in case the phosphorus should take fire. See Fig. 13.

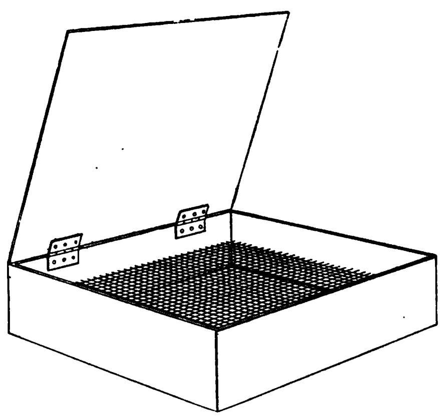


FIG. 13.

By handling phosphorus quickly with the hands, and introducing it into the metal with a shovel or a pair of tongs, it may be added without using the iron receptacle shown in Fig. 12. But if added in this way, much of the phosphorus will be oxidized and lost.

30. Aluminum in a pure state alloyed with copper in the proportions of from one-sixth to one-tenth is used as a

deoxidizing agent. It makes a good deoxidizing agent and greatly increases the strength of the castings, but has the disadvantage of increasing the shrinkage to such an extent as to make it almost impossible to get solid castings when the metal contains 10 to 11 per cent. of aluminum. Aluminum has an additional disadvantage in that it oxidizes when in contact with the air, forming a thin film of aluminum oxide on the surface of the molten metal, which may spoil the casting if permitted to pass into the mold. This film forms so rapidly that it can be seen forming on a clean stream of the molten metal as soon as it leaves the lip of the crucible.

Aluminum alloys with zinc, and when the mixture of copper, zinc, and aluminum contains 3 per cent. or less of aluminum, strong brass castings can be made from it. It is difficult to obtain solid castings when the aluminum is over 3 per cent.

When a small amount of aluminum is found to give good results in brass castings, a good way to introduce it into the copper is in the form of aluminum zinc, which contains 90 parts zinc and 10 parts aluminum.

ALLOYS AND MIXTURES.

COPPER AND TIN ALLOYS.

31. Effects of Alloying Copper With Tin.—Copper and tin have a great affinity for each other, and mix thoroughly in nearly all proportions. Tin is a soft, white metal and melts at about 440° F.; but, while both tin and copper are soft metals, their alloys are harder than the metals themselves. One part of tin will combine with 2 parts of copper in so homogeneous a manner that each metal will lose its identity, giving a compound that is gray in color and very hard and brittle. Tin greatly increases the fluidity of molten copper; the tensile strength of copper increases by the addition of tin from 1 to 12 per cent.; the

ductility of copper is decreased by the addition of tin; the ability of copper to resist crushing increases up to the addition of 18 per cent. of tin, but beyond this percentage of tin the alloy becomes hard and brittle.

32. Gun Metal.—Alloys containing from 1 to 7 per cent. of tin turn a beautiful brown color when finished. The alloy known as **gun metal** consists of copper and from 8 per cent. of tin in the soft grades to 20 per cent. in the hard grades. Gun metal is so greatly weakened by heat that the tensile strength at 500° F. is less than two-thirds that at ordinary atmospheric temperatures. The best gun metal has from 8 to 10 per cent. of tin alloyed with the copper.

Tin is supplied to the trade in pig or bar form, and is added to the copper by melting each metal separately or by adding the tin while the copper is in the furnace or after the crucible has been lifted from the furnace. There are two grades of tin, one called *grain tin* and the other *block tin;* the former, being the purer metal, is used in producing the best grades of bronze.

Some founders, using tin in the pig or block form, add it to the molten copper by holding the end of the block in the molten metal until a sufficient amount has melted off, the pig having previously been marked at the place that will give the proper weight. Others cut off pieces and immerse them separately. Some first melt the tin and cast it into small slabs or rolls of convenient size. When the tin is bought in the bar form, it is handled much more easily than otherwise.

When melting tin in a crucible, it must be watched, and removed from the fire as soon as it is melted; otherwise, the fumes, if exposed to the air, will catch fire and burn with a bright, white light.

Aften tin has been added to melted copper, the mass should be thoroughly stirred. This may be done with a rod made of plumbago or an iron rod heavily coated with graphite. The rod should be used around the sides and bottom of the crucible as well as at the middle, so as to thoroughly agitate the whole mass.

TABLE II.

SHOWING THE CHEMICAL AND PHYSICAL PROPERTIES OF THE ALLOYS OF COPPER AND TIN.

Chemical Constitution.	Composition by Weight. Per Cent. Copper.	Tin.	Specific Gravity.	Color.	Fracture.	Ultimate Cohesion Per Sq. In. Tons.	Order of Ductility.	Order of Malleability at 60° F.	Order of Hardness.	Order of Fusibility.	Characteristic Properties in Working, Etc.	Relation to Cast Iron in Presence of a Solvent, i. e., Sea-Water.
$C+$	100.00		8.667	Tile red,	*E.*	24.6	1	2	10	16	Well known.	Every alloy of $C+T$ increases the corrosive action of sea-water on cast iron in their presence. The maximum increase is due to tin.
$10C+T$	84.29	15.71	8.561	Reddish yellow, 1	*F. C.*	16.1	2	6	8	15	Gun metal, etc.	
$9C+T$	82.81	17.19	8.162	Reddish yellow, 2	*F. C.*	15.2	3	7	5	14	Gun metal, etc.	
$8C+T$	81.10	18.90	8.459	Yellowish red, 2	*F. C.*	17.7	4	10	4	13	Gun metal and bronze.	
$7C+T$	78.97	21.03	8.728	Yellowish red, 1	*V. C.*	13.6	5	11	3	12	Hard mill brasses, etc.	
$6C+T$	72.27	27.73	8.750	Bluish red, 1	*V.*	9.7	0	12	2	11	Brittle — All these alloys	
$5C+T$	72.80	27.20	8.575	Bluish red, 2	*C.*	4.9	0	13	1	10	Brittle — found occasion-	
$4C+T$	68.21	31.79	8.400	Ash gray,	*C.*	.7	0	14	6	9	Crumbles — ally in bells with	
$3C+T$	61.69	38.31	8.539	Dark gray,	*T. C.*	.5	0	16	7	8	Crumbles — mixtures of zinc	
$2C+T$	51.75	48.25	8.416	Grayish white, 1	*V. C.*	1.7	0	15	9	7	Brittle — and lead.	
$C+T$	34.92	65.08	8.056	Whiter still, 2	*T. C.*	1.4	0	9	11	6	Small bells, brittle.	
$C+2T$	21.15	78.85	7.387	Whiter still, 3	*C. C.*	3.9	0	8	12	5	Small bells, brittle.	
$C+3T$	15.17	84.83	7.447	Whiter still, 4	*C. C.*	3.1	0	5	13	4	Speculum metal of authors.	
$C+4T$	11.82	88.18	7.472	Whiter still, 5	*C. C.*	3.1	8	4	14	3	Speculum files, tough.	
$C+5T$	9.68	90.32	7.442	Whiter still, 6	*E.*	2.5	6	3	15	2	Speculum files, soft and tough.	
$+T$		100.00	7.291	White, 7	*F.*	2.7	7	1	16	1	Well known.	

Abbreviations used in the fifth column to denote character of fracture: *F. C.*, Fine Crystalline; *C. C.*, Coarse Crystalline; *T. C.*, Tabular Crystalline; *F. F.*, Fine Fibrous; *C.*, Conchoidal; *V. C.*, Vitrio Conchoidal; *V.*, Vitreous; *E.*, Earthy.

The maxima of ductility, malleability, hardness, and fusibility are 1.

The numbers in the fourth column denote intensity of shade of same color.

The ultimate cohesion was determined on prisms of .25 inch square without having been hammered or compressed after being cast. The weights given are those that each prism just sustained for a few seconds before disruption.

The copper used in these alloys was granulated and of the finest "tough pitch." The zinc was Mosselman's from Belgium and the tin "grain tin" from Cornwall. They were alloyed in a peculiar apparatus to avoid loss by oxidation and the resulting alloy verified by analyses.

No simple binary alloy of copper and zinc, or of copper and tin, works as well in turning, planing, and filing as if combined with a very small proportion of a third fusible metal—generally lead is added to $C+Z$, and zinc to $C+T$, as is known to workers in metals.

33. Chemical and Physical Properties of the Alloys of Copper and Tin.—Table II gives the composition and physical properties of a number of alloys of copper and tin. The metals were alloyed in proportion according to their atomic weights, as shown in the first column, and hence the percentages in column 2 are not expressed in even figures.

COPPER AND ZINC ALLOYS.

34. Zinc is a bluish-white metal that possesses little strength. It will take fire in the air if heated above 750° F., and in burning emits a greenish-white flame and fumes that form oxide of zinc. It may be mixed with copper up to 35 or 40 per cent. without having much effect upon the malleability and ductility of the alloy, but further additions of zinc cause the mixture to become brittle; for instance, an alloy containing 2 parts of zinc to 1 part of copper is so brittle that it may be readily crushed in a mortar.

35. Brass and Bronze.—When zinc is alloyed with copper without other metals, it gives the mixture called **brass**; while tin alloyed with copper, gives **bronze.** When the mixture is composed of 66 parts copper and 34 parts zinc, we have the alloy commonly used for brass castings; although, from 2 to 4 per cent. of tin is often added, as it gives greater strength to the castings.

Zinc gives fluidity to the alloys and is an excellent deoxidizing agent for the copper, assisting in obtaining sound castings. When a high percentage is used, however, to give extra fluidity to brass that is to be used in making thin castings, care must be taken that the metal is not poured when it is too hot, else it may boil or **kick** out of the mold.

In making brass castings, a good color is one of the features desired. A mixture that gives good results for this purpose consists of 16 parts of copper and from $\frac{3}{4}$ to 1 part each of tin, zinc, and lead. If this mixture is poured into molds made from a fine grade of sand, very fine light castings having a good color may be obtained.

TABLE III.

SHOWING THE CHEMICAL AND PHYSICAL PROPERTIES OF THE ALLOYS OF COPPER AND ZINC.

Chemical Constitution.	Composition by Weight. Per Cent. Copper.	Tin.	Specific Gravity.	Color.	Fracture.	Ultimate Cohesion Per Sq. In. Tons.	Order of Ductility.	Order of Malleability at 60° F.	Order of Hardness.	Order of Fusibility.	Characteristic Properties in Working, Etc.	Relation to Cast Iron in Presence of Solution, i.e., Sea-Water.
$C+$	100.00		8.667	Tile red,	*E.*	24.60	8	1	12	15	Well known. Several of these are malleable at high temperatures.	All these alloys increase the corrosion of cast iron in sea-water when in their presence.
$10C+ Z$	90.70	9.30	8.605	Reddish yellow, 1	*C. C.*	12.21	6	13	21	14		
$9C+ Z$	89.80	10.20	8.607	Reddish yellow, 2	*F. C.*	11.50	4	11	20	13		
$8C+ Z$	88.70	11.30	8.633	Reddish yellow, 3	*F. C.*	12.80	2	10	19	12	Similar, etc.	
$7C+ Z$	87.70	12.30	8.587	Reddish yellow, 4	*F. C.*	13.20	9	9	18	11		
$6C+ Z$	85.08	14.92	8.591	Yellowish red, 3	*F. F.*	14.10	5	8	17	10		
$5C+ Z$	83.02	16.98	8.415	Yellowish red, 2	*F. C.*	13.70	11	2	16	9	Bath metal	
$4C+ Z$	79.65	20.35	8.448	Yellowish red, 1	*F. C.*	14.70	7	3	15	8	Dutch metal.	
$3C+ Z$	74.58	25.42	8.397	Pale yellow,	*F. C.*	13.10	10	4	14	7	Roll sheet brass.	
$2C+ Z$	66.18	33.82	8.299	Full yellow, 1	*F. C.*	12.50	3	6	13	6	British brass.	
$C+ Z$	49.47	50.53	8.230	Full yellow, 2	*C. C.*	9.20	12	5	12	6	German brass.	
$C+ 2Z$	32.85	67.15	8.283	Deep yellow,	*C. C.*	19.30	1	7	10	6	Brass, watchmakers'.	
$8C+17Z$	31.52	68.48	7.721	Silver white, 1	*C.*	2.10		22	5	5	Very brittle. Too hard to file or turn, luster nearly equal to speculum metal.	All these alloys decrease the corrosion of cast iron in sea-water when in their presence.
$8C+18Z$	30.30	69.70	7.836	Silver white, 2	*V. C.*	2.20		23	6	5	Very brittle	
$8C+19Z$	29.17	70.83	8.019	Silver gray, 3	*C.*	.70		21	7	5	Very brittle	
$8C+20Z$	28.12	71.88	7.603	Ash gray, 3	*V.*	.20		19	3	5	Brittle	
$8C+21Z$	27.04	72.96	8.058	Silver gray, 2	*C.*	.90		18	9	5	Brittle	
$8C+22Z$	26.24	73.76	7.882	Silver gray, 1	*C.*	.80		20	8	5	Very brittle	
$8C+23Z$	25.39	74.61	7.443	Ash gray, 4	*F. C.*	5.90		15	1	5	Barely malleable.	
$C+ 3Z$	24.50	75.50	7.449	Ash gray, 1	*F. C.*	3.10		16	2	4	Brittle.	
$C+ 4Z$	19.65	80.35	7.371	Ash gray, 2	*F. C.*	1.90		14	4	3	White button-metal.	
$C+ 5Z$	16.31	83.69	6.605	Very dark gray,	*F. C.*	1.80		17	11	2	Brittle.	
Z		100.00	6.895	Bluish gray,	*T. C.*	15.20	13	12	23	1	Brittle, well known.	

36. Alloying Copper With Zinc.—In adding zinc to copper, it may, when added in small quantities, be inserted in the molten copper by means of a pair of tongs, when it will be thoroughly melted by the heat of the copper; in the case of adding a large quantity, it should be melted along with the copper, by being charged into the crucible as soon as the copper commences to melt. It may also be melted separately and poured into the copper through a hole made for the purpose through the charcoal covering over the copper or through a hole in an iron cover; such a cover is the best thing to use to prevent oxidation. If the metal is not kept covered, the zinc will volatilize rapidly, causing a vapor that, in burning, creates an oxide that settles around the shop in the form of flakes. Where tin is added to the copper, it is put in immediately after the zinc.

As zinc costs but from one-fourth to one-third as much as copper or tin, it is used in commercial work whenever the castings made from it will answer the purpose.

Table III gives the composition and the physical properties of alloys of copper and zinc.

LEAD AND COPPER ALLOYS.

37. Lead.—The specific gravity of **lead** is 11.35, and it melts at 612° F. The addition of lead to brass or bronze castings decreases their strength and changes their color, and also makes them corrode more easily. Lead and copper have little affinity for each other, and will only mix in a satisfactory manner when the lead does not exceed about 3 per cent. It will scarcely combine with zinc, and a combination of them is only made by adding a small percentage of arsenic. However, lead will assist in giving the castings a smooth surface, as it forms an oxide of lead on the surface that prevents the molten metal taking too sharply the impression of the sand. A small amount of lead is added to brass castings to facilitate the work to be done on them in the machine shop.

Lead is used a great deal in the manufacture of *Babbitt metal*, which is used in the construction of bearings for the journals of shafts and spindles; some castings of this character contain as much as 10 per cent. of it in mixture with copper and tin, no zinc being used. It is added to the copper in the same manner as zinc or tin. As it is much cheaper than copper, zinc, or tin, it is used as much as possible by some founders. An excess of it is readily detected by the color and the lack of homogeneity shown when the casting is broken.

Lead is used for other alloys than bronze and brass; it is alloyed with antimony for making type metal, with bismuth for fusible alloys, and with arsenic for making shot.

MANGANESE IN ALLOYS.

38. Manganese has a specific gravity of about 7.5. It is of a whitish-gray color, of high metallic luster, and is sufficiently hard to scratch glass. It is alloyed with iron and copper—in iron as ferromanganese and with copper as manganese copper, which is its best form for the use of brass founders, as in the form of ferromanganese it introduces the iron into the alloys of brass, much to their injury. An alloy of about 70 parts of copper to 30 parts of manganese is on the market, and is used in copper mixtures to give manganese alloys a range in manganese from a trace up to 5 per cent. It can be mixed with copper to give a metal that may be forged. It is said to give good bearing and journal castings, and is used extensively in casting propeller wheels, both on account of its strength and ductility. Propeller wheels made of this metal are made thinner than is permissible with other metals, because, if bent, they may be straightened again; although it is better to cast them so thick that they will retain their shape when they strike an obstacle when in action.

Manganese bronze does not corrode easily, and for this reason is used in the form of sheets for mining screens, since

the acid mine waters have no effect on it. It weakens somewhat, however, when heated, and has a greater percentage of shrinkage than gun metal.

A mixture found to work well in journals and similar castings is as follows: Copper, 40 parts; tin, 3¼ parts; zinc, 2¼ parts; and manganese, 2½ parts. Another mixture suitable for propellers, gear-wheels, and heavy machinery is: copper, 54 parts; zinc, 40 parts; tin, 2¼ parts; and manganese, 3¾ parts. To make metal suitable for the sheets of mining screens, more copper and manganese and less zinc are required. When the alloy is very high in manganese, it may require chilled molds for casting; whereas with less manganese, the castings can be made in sand molds.

To make a metal that resembles German silver, and that has high electrical resistance, the following mixture may be used: Copper, 67¼ parts; manganese, 18½ parts; zinc, 13 parts; and aluminum, 1¼ parts.

BISMUTH IN ALLOYS.

39. Bismuth.—The specific gravity of **bismuth** is 9.8, and it melts at about 500° F., but as an ingredient in alloy with other metals, the melting point is lower, one form of solder containing bismuth melting at 212° F. It is very brittle, a little harder than lead, and has a yellowish-white color. As sold commercially bismuth is not pure, containing iron and arsenic. It possesses the peculiar property of expanding while cooling, which makes it very valuable in connection with some forms of castings, especially printers' type.

When alloys having bismuth as a constituent are used in casting, the castings should be cooled as rapidly as practicable, as otherwise the bismuth may separate from the other metals and weaken the castings.

Mr. Erwin S. Sperry concludes, as the result of five experiments on alloys having about 60 parts of copper, 40 parts of zinc, and bismuth that varied from .5 to .02 of

1 part, that bismuth causes brass to be cold short and hot short, and to have both visible and latent fire-cracks; also, that high brass for cold rolling should not contain over .01 per cent. of bismuth. It is not known whether Mr. Sperry knew that it was essential that castings containing bismuth should be rapidly cooled, which is important in remedying the defects to which he refers. If he did cool his castings rapidly and then got those results, it would indicate that bismuth was not a desirable material to mix with brass.

ANTIMONY AND BABBITT METALS.

40. Antimony is a metal having a brilliant silvery-white color. Its specific gravity is 6.7, and it melts at 830° F. At common temperatures it does not oxidize. It unites with sodium, potassium, and lead, forming with them a more homogeneous mixture than does any other metal. In alloy with other metals, it hardens and whitens them, and the alloy contracts very little while cooling. For these reasons it is an excellent metal to use in making printers' type and plates. It is used for type metal, in the manufacture of pewter articles, antifriction alloys, etc. In the manufacture of type metal, 1 part of antimony is used to 4 parts of lead, and for stereotyping plates there is added to this $\frac{1}{20}$ to $\frac{1}{50}$ part of tin.

A very hard pewter is made from 8 parts of antimony, 2 parts of copper, and 96 parts of tin. By increasing the copper, a softer pewter can be made. In making Britannia metal, 8 parts of antimony, 2 of bismuth, 2 of copper, and 100 parts of tin are melted together.

41. Babbitt metal was named from the inventor of the journal-box in which antifriction metal was first used. Its original composition, so far as known, was 89.3 per cent. of tin, 7.1 per cent. of antimony, and 3.6 per cent. of copper. It is claimed by some writers that the original composition was 83.3 per cent. of tin, 8.3 per cent. of antimony, and 8.4 per cent. of copper.

Babbitt metal is made that varies considerably in the amounts of the various constituents, as tin, copper, antimony, bismuth, zinc, and lead, in order to make the metal suitable for the various conditions of bearings, weight, and speed of rotation of the shafts and spindles for which it is used.

Antimony is used largely in the composition of the best grades of Babbitt metal; these are made with tin as the principal constituent, the ones next in importance being antimony, and a small percentage of copper; no lead is used in what is termed the genuine Babbitt metal. Antimony gives hardness to the Babbitt, while the tin gives the antifriction qualities. Owing to the difference in the cost of lead and tin, there is a temptation to adulterate with lead. The grades having lead as a constituent should not be used in bearings that support heavy loads or have great friction. The addition of lead to Babbitt metal may be determined by rubbing the metal on paper; if lead is present, it will leave a mark somewhat similar to that made by a lead pencil.

Among the soft metals in use, it is claimed that none of them has greater antifriction properties than lead; but on account of the impracticability of keeping it in the journal-boxes, it cannot be used in the pure state.

Lead and antimony have the property of combining with each other without impairing their antifriction quality. The following mixture of them is said to be excellent for light, high-speed machinery: 80 parts of lead, by weight, mixed with 20 parts of antimony. In using it, however, it must never be heated sufficiently to scorch a splinter of dry pine.

In making Babbitt metal, the copper is first melted and the antimony added, and then about 10 or 15 pounds of tin, the whole being kept at a dull-red heat and constantly stirred until the metals are thoroughly mixed, after which the balance of the tin is added, and after being thoroughly stirred it is cast into ingots. In melting the alloy to pour it into journal-boxes, it should be kept carefully covered with charcoal to prevent the antimony from vaporizing. This metal

TABLE IV.

COMPOSITION OF BEARING METALS.

Metals.	Copper.	Tin.	Lead.	Zinc.	Antimony.	Iron.
Camelia metal	70.20	4.25	14.75	10.20		.55
Antifriction metal	1.60	98.13				Trace
White metal			87.92		12.08	
Car brass lining		Trace	84.87		15.10	
Salgee antifriction	4.01	9.91	1.15	85.57		
Graphite bearing metal		14.38	67.73		16.73	(?) (1)
Antimonial lead			80.69		18.83	
Carbon bronze	75.47	9.72	14.57			(2)
Cornish bronze	77.83	9.60	12.40	Trace		Trace (3)
Delta metal	92.39	2.37	5.10			.07
American antifriction metal			78.44	.98	19.60	.65
Tobin bronze	59.00	2.16	.31	38.40		.11
Graney bronze	75.80	9.20	15.06			
Damascus bronze	76.41	10.60	12.52			
Manganese bronze	90.52	9.58				(4)
Ajax metal	81.24	10.98	7.27			
Antifriction metal			88.32		11.93	
Harrington bronze	55.73	.97		42.67		.68
Car-box metal			84.33	Trace	14.38	.61
Hard lead			94.40		6.03	
Phosphor-bronze	79.17	10.22	9.61			(5)
Ex. B. metal	76.80	8.00	15.00			(6)

OTHER CONSTITUENTS.

(1) No graphite.
(2) Possible trace of carbon.
(3) Trace of phosphorus.
(4) No manganese.
(5) Phosphorus, .94.
(6) Phosphorus, .20.

when carefully prepared is probably one of the best in use for lining boxes that are subjected to a heavy weight and wear.

42. Composition of Bearing Metals.—Table IV gives the constituents of the most prominent of the bearing metals, as analyzed in the Pennsylvania Railroad laboratory at Altoona, Pennsylvania.

PHOSPHORUS AND PHOSPHOR-BRONZE.

43. Phosphorus is a soft, translucent, colorless solid of a waxy consistency, having a specific gravity, when solid, of 1.83, and a melting point of 111° F. It increases the fluidity of some alloys, and increases the strength and ductility of the castings made from them. It is an excellent flux to use with copper because of its deoxidizing properties. It is the best agent known for reducing the shrinkage of the brass alloys, but when poured hot, it causes the metal to eat into the face of the mold, and so produces rough castings; for this reason the best results are secured with some **phosphor-bronze** castings when they are made in dry-sand molds.

Phosphorus reduces the strength of castings that are subjected to high temperatures, and will cause them to crack readily. It is alloyed with bronze in amounts that range from a few hundredths of 1 per cent. to 2 per cent.; but it does not always combine thoroughly with these bronze mixtures, and may cause hard spots in the castings. It is best added to alloys of copper, tin, and lead in the form of phosphor-copper, which is copper containing from 4 to 6 per cent. of phosphorus, and which is made by melting copper in a crucible and adding the phosphorus in the manner already described. Phosphor-tin is made by melting the tin separately and adding the phosphorus in the same way as for making the phosphor-copper.

Where the quantity of metal to be cast is small and does not warrant the making of the phosphor-copper or phosphor-tin, the phosphorus may be added to the alloy in the stick form, as already described.

44. Mixtures for Phosphor-Bronze Bearing Metals.—Table V gives the composition of the phosphor-bronze used by three of the prominent railroad companies of the United States.

TABLE V.

MIXTURES FOR PHOSPHOR-BRONZE BEARING METAL.

Number of Mixture.	Copper. Per Cent.	Lead. Per Cent.	Tin. Per Cent.	Phosphorus. Per Cent.
1	79.0	10.0	10	1.0
2	79.7	9.5	10	.8
3	79.7	10.0	10	.3

SCRAP METAL FOR BRASS AND BRONZE CASTINGS.

45. In the discussion of alloys, it has been so far assumed that new metal was used. As a rule, however, brass founders use more or less scrap metal, and many use scrap entirely, adding copper or lead to soften the mixtures, and tin or antimony to harden them; zinc is often used as an intermediate metal to change them slightly, vary the color, increase the fluidity, and to act as a flux. Furthermore, phosphorus and lead are used to give the peculiar qualities that they impart. In using all scrap metal, founders mix the scrap in such proportions as to regulate the color, degree of hardness, etc. that they wish to obtain, and so save the expense of new metal.

46. Grading Scrap Brass.—Scrap brass is graded by the color of its fracture, and is known as yellow, red, or white brass. The yellow brass is the most difficult to sort as to quality, as it may have any of the properties of the others, and, hence, is best used in small quantities in conjunction with the other varieties.

When the scrap has a reddish-colored fracture, it is generally an indication that it is rich in copper, and is a soft metal; if it has a light-colored fracture, it is assumed that it is rich in tin or antimony, or both, and is hard. By taking equal parts of each of these alloys and mixing them with from one-fourth to one-half of good copper, using a small quantity of lead in the molten metal to act as a flux, an excellent metal for journals and thick machinery castings is obtained.

When putting the lead in as a flux, the molten metal should be thoroughly stirred with a rod around the sides of the crucible; in fact, this should be done with all scrap mixtures, as well as with new metal, as it assists in bringing the oxides and occluded gases to the surface, where they may be removed or will pass into the air. In skimming the oxides, it is well to remember that new surfaces are being exposed to the air to form more oxides, and that the sooner the metal is poured after being skimmed, the better is the chance of getting clean, sound castings.

47. Using Brass Borings and Turnings.—Where the brass foundries are operated in connection with machine shops, there are usually quantities of borings and turnings from the shop to be used in the foundry. In such cases the borings, etc. are packed in a crucible and melted, after which solid scrap or new metal is added and melted and mixed with the scrap, the mixture then being treated as though only solid material had been used. No iron chips should be introduced with the mixture. Where there are iron filings and chips in the mixture, they may be removed by the aid of a magnet or by running the mixture through a magnetic separator.

48. Report on Journal-Bearing Metals.— In a report from a prominent railroad master mechanic on journal-bearing metals, the advisability of making the bearings entirely of new metal or mostly of scrap material, is discussed as follows: "It is manifestly absurd to charge all sorts of disreputable scrap into a crucible and expect to pour

out high-grade phosphor-bronze. The ordinary run of scrap available for use in car bearings is found to contain zinc and, generally, an insufficient amount of tin. The presence of zinc in moderate quantities is not necessarily a serious detriment, as more or less zinc is vaporized off in the melting. If tin is lacking, its deficiency should not go unfilled; enough tin should be added to form a proper alloy and give the metal fluidity. Of course, tin is a high-priced metal, but its moderate use is often necessary to obtain proper results. As is well illustrated under the microscope, lead does not chemically alloy with the bronze, but is held in the mixture mechanically, very much as water is held in a sponge; as much lead should be added as the alloy will hold up or absorb. This is desirable for a twofold purpose: lead improves the bearing qualities of the alloy and at the same time cheapens the cost per pound. One of the most troublesome conditions encountered in the production of bronze bearing metals is the great affinity that oxygen has for copper and its alloys in the molten state. If care is not taken in excluding oxygen from the metal, the resulting bearing on being fractured will show discolored oxide spots, which in a car bearing is fatal to cool running. The oxide, being harder than the unoxidized portion of the metal, is pretty certain to give trouble, for the hard spot, if occurring in the bearing surface, is almost certain to form the nucleus for a 'copper spot' and be the cause of a hot bearing."

BLACKSMITHING AND FORGING.

(PART 1.)

IRON AND STEEL.

1. Definition of Forging.—**Forging,** or **blacksmithing,** is the hammering or pressing of metal (iron or steel) into required shapes. This may be done while the metal is hot or cold, as the circumstances require.

KINDS OF IRON.

2. Pig Iron.—Iron ore is taken from the mine, put into a furnace together with fuel (coal, coke, or charcoal) and a flux (generally limestone), and melted under a forced draft, the ore being reduced to metallic iron. When a sufficient quantity of molten iron has collected in the bottom of the furnace, the tap hole is opened and the iron is allowed to run out into ditches, from which it flows into side pockets, where it is allowed to cool. When just set, the pieces are broken apart, forming the **pig iron** of commerce.

3. Cast Iron.—The pig iron may again be melted in a cupola and cast in molds. It is then known as **cast iron;** it is hard, brittle, and crystalline in structure. Pure iron is tough, ductile, and malleable, so that cast iron must owe its properties to some foreign substance. A chemical analysis shows that cast iron contains *carbon;* the amount

varies greatly, and with it the tenacity and malleability of the iron. Carbon, then, is one of the foreign substances that makes iron hard and brittle. The iron absorbs the carbon from the fuel with which it is melted ; some of it is merely mechanically mixed with the iron, while some is in actual chemical combination.

4. Wrought Iron.—Extracting the carbon makes the iron malleable and ductile. The carbon may be burned out by forcing a blast of air through it or across its surface while molten. In this way the particles of carbon are brought into contact with the oxygen of the air, forming carbonic-acid gas, CO_2. When the carbon has been burned out, the iron is cast or formed into ingots or blooms, which are rolled and forged into bars or shapes. Charcoal, coal, coke, oil, or gas may be used as fuel for heating or melting the iron. Charcoal, however, being free from sulphur and other impurities so common in coal and coke, is the best fuel. The excellence of the Swedish iron is due partly to the purity of the ore, and partly to the fact that charcoal is used for fuel in smelting it. Good charcoal iron can be tied into a knot while cold without breaking, or it may be bent double, pounded down, and then straightened without cracking.

5. Puddle Iron.—The puddling process, which is now generally used for the production of wrought iron, consists in melting a quantity of cast iron on an open hearth and then adding small quantities of iron ore. Cast iron contains carbon and the iron ore contains oxygen; the oxygen combines with the carbon, making carbonic-acid gas, CO_2; this, and the combination of the carbon and other foreign substances in the iron with the gases of the fuel as they pass over the iron, removes nearly all impurities, leaving the iron nearly pure.

6. Fagot Iron.—Fagot iron is made by subjecting scraps of wrought iron to a welding heat and then welding them together under a heavy hammer. The blocks or billets are then hammered or rolled out into bars or shapes.

KINDS OF STEEL.

7. Characteristics of Steel.—It has been seen that it was the carbon in the cast iron that was the principal factor in making it hard and brittle, while extracting the carbon left the wrought iron soft and ductile. It is evident that some point exists where the amount of carbon is such that the product has some of the characteristics of each; that is, where it has some of the ductility and malleability of wrought iron and the hardness and brittleness due to the carbon. When this point is reached, the product is termed steel. It is tough, but at the same time the carbon that it contains enables it to acquire a great degree of hardness. The hardening is accomplished by chilling the metal suddenly, and the degree of hardness depends on the amount of carbon contained and on the rapidity with which it is chilled from a cherry-red heat.

8. Comparison of Wrought Iron and Steel.—Wrought iron is fibrous in its structure, but steel has lost its fibrous structure and is crystalline. Steel is improved by working it at the proper temperature. Owing to the variation in the carbon contained in the different kinds of steel, the different grades require different treatment in forging and tempering. Steel of good quality is homogeneous throughout, that is, it is of the same consistency and structure. In the poorer grades two pieces cut from the same bar may show different results under the same treatment; such steel is not homogeneous.

MANUFACTURE OF TOOL STEEL.

9. Puddle Steel.—This is made by melting cast iron on a shallow open hearth built of firebrick. When the iron is in a molten condition, small scraps of wrought iron are thrown into it, the mass being stirred continually until it becomes granular and spongy. The cast iron being high in carbon and the wrought iron comparatively pure, it is evident that by judiciously proportioning the amounts of

each, a mixture can be obtained containing any desired per cent. of carbon. The product is then hammered and worked into suitable bars.

10. Blister Steel.—This is made by packing bars of good charcoal iron (generally $\frac{3}{4}$ inch square) into tight iron boxes with powdered charcoal, bone ash, or some other form of practically pure carbon. This is subjected to a cherry-red heat for a number of days (7 to 14 days). The iron absorbs a certain amount of the carbon, which gradually penetrates to the center. The bars are then taken out and found to be covered with scale or blisters. These are scraped off and the bars heated to a cherry red for a few days to distribute the carbon more evenly throughout.

11. Shear Steel.—For shear steel, the bars of blister steel are cut up and then brought to a welding heat and welded together under a heavy hammer. After this they are rolled out into bars.

12. Double-Shear Steel.—If the bars of shear steel are again cut up and the short pieces welded into a block and then rolled out into bars, the product is called **double-shear steel.** This gives still greater uniformity of structure than the single-shear steel; tools made from double-shear steel take a very fine temper.

13. Crucible Steel or Cast Steel.—In order to obtain still greater uniformity in the composition of the steel, the bars of blister steel are frequently broken into small pieces and melted in a crucible. The metal is then cast into ingots, which are rolled into bars and put on the market as **crucible steel** or **cast steel.** This process produces a very fine quality of steel, which is used for the best grades of instruments and edged tools.

14. Blister steel and its products are now comparatively little used, except for certain high-grade tool steels. The larger portion of the tool steel now manufactured is made by taking high-grade wrought iron (Swedish iron being

commonly used for this purpose) and packing it in pots with the requisite amount of charcoal, sealing a cover on the pots, and melting the entire charge down together. Many of the modern pot furnaces are fired by gas. The melting pots are drawn one after the other and their contents poured into a large ladle. This mixes the charge from all the pots, thus insuring a more uniform grade of steel. The contents of this large ladle are then poured into ingot molds, and these ingots are subsequently worked down under hammers or with rolls. The best tool steel is worked down entirely under hammers.

15. Laminated Steel.—This is made by coiling steel wire around a *core* and then welding the rings together. It is very elastic and tough and stands a great strain. It is used principally for gun barrels.

16. Fagot steel is made of scraps of steel in the same way as fagot iron; the quality of the product depends on the quality of the scraps used.

17. Treatment of Tool Steel.—Of the different grades of tool steel, that which is sold under the name of shear steel will stand a higher temperature than many of the other brands. The temperature that steel will stand depends very largely on its percentage of carbon; the highest grade of steel, containing $1\frac{1}{2}$ per cent. carbon, has to be worked with very great care. This is also true of the steel used in the manufacture of some files, which contains $1\frac{5}{8}$ per cent. carbon. These high-carbon steels cannot be welded. Ordinary high-grade tool steel containing $1\frac{1}{4}$ per cent. carbon can be welded if great care is used, and will stand a much higher heat in forging than the higher carbon steels, and as the percentage of carbon decreases, the heat at which the steel can be worked increases. No high-carbon steel should be heated to more than a mild cherry red.

18. Steel is improved by working, if care is taken to guard against burning it, and it will stand more working than iron. It is better to work steel by a rapid succession

of medium hammer blows than by pounding it down suddenly with heavy blows.

19. Self-Hardening Steel.—Self-hardening steel is a special cast steel to which some other elements besides carbon have been added. Wolfram or tungsten and chromium are among the elements commonly used. Steels of this general class are simply forged to the desired shape, heated to the proper temperature, and allowed to cool in the air, or in a blast of air, when they will be found sufficiently hard for use. Special processes, as, for instance, the Taylor-White process of the Bethlehem Steel Company, have been invented for treating these self-hardening steels and rendering them able to hold their temper even when quite hot (a dull-red heat), thus enabling the cutting speed of the tools to be greatly increased. Self-hardening steel tools are rarely if ever used for finishing work, their sphere of usefulness being as roughing tools.

SOFT, OR MILD, STEEL.

20. Bessemer Process.—Soft steel, or mild steel, is a steel that contains very little carbon; it is scarcely more than good iron just beginning to show some of the characteristics of steel. The Bessemer process consists of forcing a blast of air through the molten mass of cast iron, thus burning out the carbon. The required amount of carbon is then supplied by the addition of *spiegeleisen*, which is an iron containing manganese and carbon. This manganese enables the iron to hold a large amount of carbon, the exact percentage being ascertained by a chemical analysis. When thoroughly mixed, the steel is cast into ingots, which are rolled and forged into the required forms.

21. Siemens-Martin Process.—Gun parts, boiler plates, etc. are often made of steel that is made by what is known as the **open-hearth,** or **Siemens-Martin,** process. In this process cast iron is melted in an open-hearth furnace and scrap wrought iron or steel and iron ore is added.

22. Carbon Contents of Iron and Steel. — The amount of carbon which the different kinds of iron and steel contain can be seen in the following tables:

Cast iron..............	2% to 6%.
Tool steel.............	½% to 2%.
Mild steel.............	¼% to ½%.
Wrought iron..........	Traces.

Different kinds of steel, with varying amounts of carbon, are suited for different purposes, as follows:

.5% carbon for hot work, battering tools, hammers, etc.
.6 to .7% carbon for dull-edged tools.
.7 to .8% carbon for cold sets and hand chisels.
.8 to 1% carbon for chisels, drills, dies, axes, knives, etc.
1 to 1.2% carbon for axes, knives, large lathe tools, large drills, and dies. (If used for drills and dies, great care is required in tempering.)
1.2 to 1.7% carbon for lathe tools, small drills, etc.
.9 to 1% carbon is the best all around tool steel.

SHOP EQUIPMENT.

GENERAL CONSIDERATION OF FIRE.

23. Combustion. — In the combustion of fuel (charcoal, coal, or coke), the oxygen of the air combines with the carbon of the fuel. The chemical combination produces heat; the temperature attained depends on the rapidity with which this combination takes place, and the amount of heat depends on the amount of carbon and oxygen combining. Under ordinary conditions, the combustion would not go on rapidly enough to generate sufficient heat to raise iron or steel to the temperature necessary to soften it sufficiently for working under the hammer. Artificial draft is produced in order to supply more oxygen to the fuel, and thus increase the rate of combustion. It is possible, however, to supply

too much air and blow the fire out, because too much cold air will chill the hot coals below the temperature at which the oxygen will combine with the carbon, or it may only lower the temperature by using the heat of the fire to warm the excess of air that passes through it. If an excess of oxygen is supplied to the fire, some of it will combine with the iron, forming a scale of oxide of iron. Such a fire is called an *oxidizing fire*, but if all the oxygen is used in the combustion and there is an excess of carbon, the fire is called a *reducing fire*.

24. Fuels.—Charcoal, coke, coal, oil, and gas are some of the fuels that may be used in forging. Of the solid fuels, charcoal is best on account of the small amount of impurities that it contains. Coke or small sized bituminous coal is very good if free from sulphur and phosphorus. Sulphur makes the iron *hot short*, that is, it makes it brittle while hot. Phosphorus makes the iron *cold short*, that is, it makes it brittle when cold. Sulphur, lead, bronze, or brass must never be allowed to get into the fuel nor into a fire that is to be used for iron or steel later on. A weld may be spoiled by throwing some brass filings into the fire.

FORGES.

25. Brick Forge.—A very serviceable form of brick forge is shown in Fig. 1. It is built up of brick 2 feet 2 inches or 2 feet 4 inches high. For ordinary work, the side *a b* may be 2 feet 6 inches to 3 feet long, and the side *b c*, 3 to 4 feet long. An iron water trough 6 or 8 inches wide is fastened along the edge *b c*, the coal is heaped on the forge at *f*, a cinder pit is built in the bottom, into which the cinders are emptied from the fire; a sheet-iron conical hood is spiked against the chimney over the fire to catch the smoke and cinders and lead them into the stack. The tuyere *v* is set 12 to 16 inches in front of the chimney; the blast is controlled by means of the handle *k*, and the ash door by means of the weighted handle *s*.

26. Iron Forge.—The iron forges are made with a cast-iron bowl supported on legs. The tuyere is fastened in the bowl and the blast is supplied either from a stationary blower, or bellows, or from a small blower secured to the forge. The

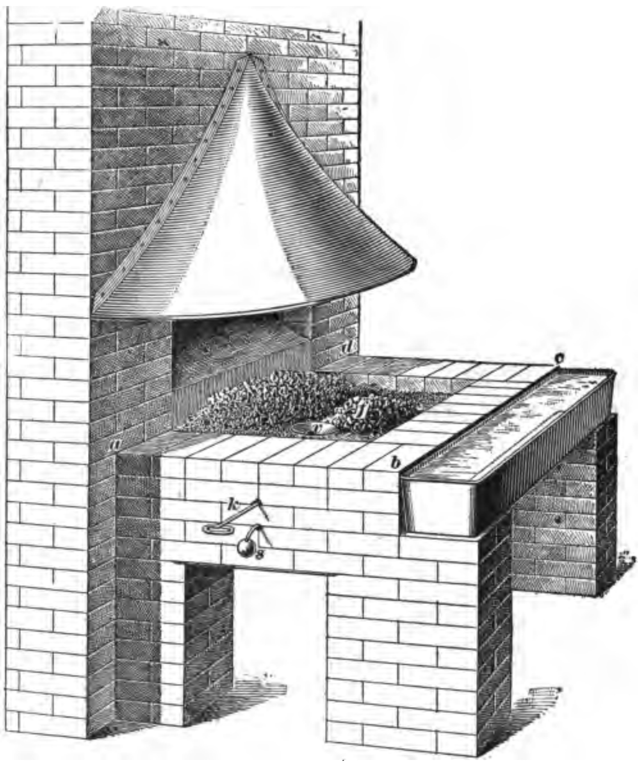


FIG. 1.

blower may be driven by a crank, a treadle, or a lever working with a ratchet. Fig. 2 shows a semiportable forge designed for fairly large work. It has no hood to obstruct the handling of the work. The blast is supplied from the blast pipe or from a small portable blower mounted on a separate stand; *a* is a rest for long pieces; it is supported by the foot *b*; *c* is the coal trough and *d* the water trough; *e* is the top of the tuyere; the blast connection is made at *f*, and the ash chute is shown at *g*.

27. Portable Forge.—Fig. 3 shows a portable forge that has a cast-iron bowl *a* supported on legs made of iron

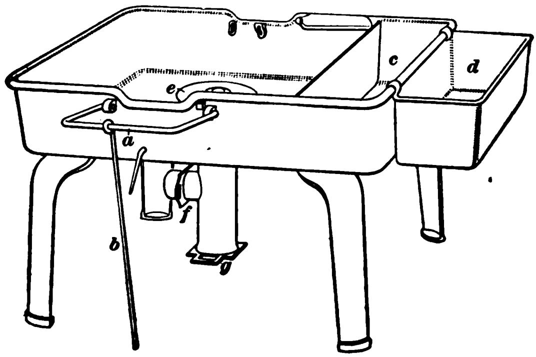


FIG. 2.

pipes. The blast is supplied from a small rotary fan *f*, secured beneath the bowl. The fan is operated by the lever *b* connected with a lever *d* carrying a ratchet on its outer end that engages with the ratchet teeth on the inside of the gear *c*.

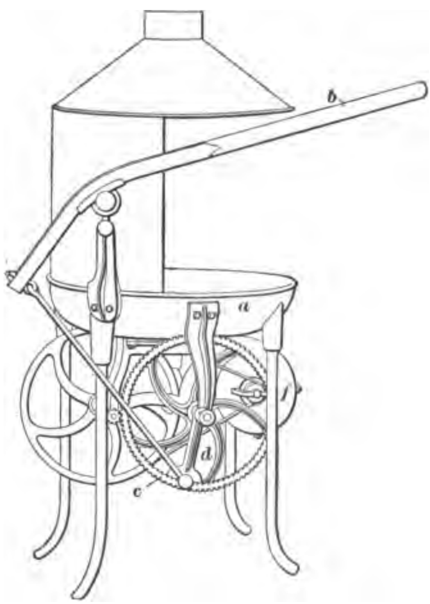


FIG. 3.

28. The Tuyere. The casting through the base of which the blast is supplied is called the **tuyere** (pronounced *twee'-er*). This is generally a cast-iron pot, or shell, with a hole through the bottom connecting with the air duct. In this air duct, or in the tuyere itself, there is a shutter or a valve for

regulating the air supply. Besides this there is generally a hole in the bottom that may be opened to drop the cinders

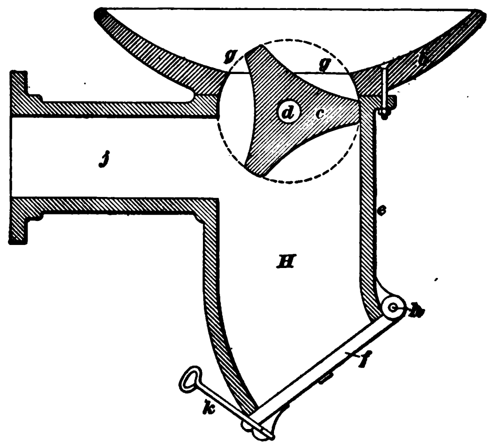


FIG. 4.

out of the fire into the cinder pit below. Figs. 4 and 5 show two styles of tuyeres, the one illustrated in Fig. 4 being shown in section. The dish-shaped fire-pot *b* has a circular hole *g* in the bottom, below which the valve *c* turns on the axis *d*. The blast enters through the pipe *j*. The tube *e* is closed at the lower end by the shutter *f*, which is hinged on the pin *h*. When cinders have collected in the space *H*, the shutter *f* is opened by means of the rod *k* and the cinders are dropped out. By turning the rod *d*, the ball valve is brought

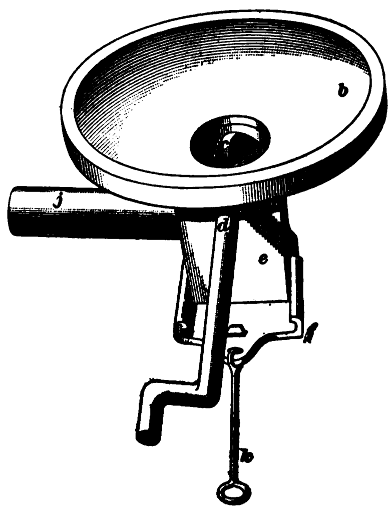


FIG. 5.

into different positions, thus increasing or diminishing the openings at *g*. The tuyere shown in Fig. 5 is similar to the other, but is of a simpler and cheaper construction. The parts are lettered as in Fig. 4.

THE BLAST.

29. The Bellows.—The **blast** is produced either by means of a rotary fan or blower, or by a pair of **bellows.** The bellows illustrated in Fig. 6 consist of two parts, the lower and upper bellows. They are separated by a partition, and the air from the lower half is forced through the valves *f* in the center board into the upper chamber, where it is stored for use. The bellows are hung from the center board by the pins *m*, and as the lower board is forced up, the air is pressed through the valves *f* into the upper

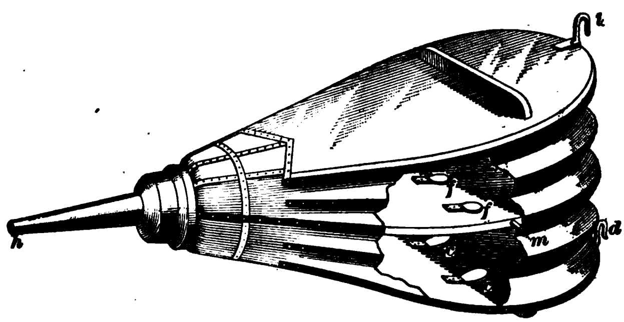


FIG. 6.

chamber, inflating it and raising the top board. As the bottom board descends, the valves *f* close and the valves *c* open, allowing air to flow in and fill the space below the center board. By fastening a weight to the top board the pressure is increased. There should be a hook and chain suspended from the ceiling, on which the top board of the bellows may be hung by the hook *l* when not in use. This will keep the leather stretched while the bellows are idle and will prevent its cracking. With this care, the bellows will last much

longer, for if the upper part is always crushed together, the leather will soon crack and the upper part will be spoiled while the lower half is still in good condition. The operating chain or rod is attached to the hook *d*, and the air from the upper part discharges through the tube *h*. The leather of the bellows should be oiled two or three times a year with neatsfoot oil or harness oil to preserve it. It should always be oiled before cold weather sets in so as to make it pliable during the winter. On a cold morning the bellows should be started slowly so as not to crack the leather while it is stiff with the cold.

30. Rotary Blower or Fan.—The rotary blower or centrifugal fan, Fig. 7, has a number of blades set nearly radially on the shaft and placed within a cylindrical iron casing. An inlet hole *d* is placed concentric with the shaft, and an outlet, opening into the delivery pipe *k*, is left at the periphery of the casing. The shaft is driven by a belt passing over the pulley *e*. The rapid revolution of the blades throws the air out centrifugally, that is, away from the center, but it cannot escape until it comes to the outlet hole. The outside air close to the shaft rushes in to fill the space, and so a constant blast is maintained. Ordinarily, a blast of from 4 to 6 ounces to the square inch, or, approximately, 7 to 10 inches of water, is maintained. A pressure of 1 pound to the square inch is equal to the pressure of a column of water with an area of 1 square inch and 27.7 inches high, and the pressure

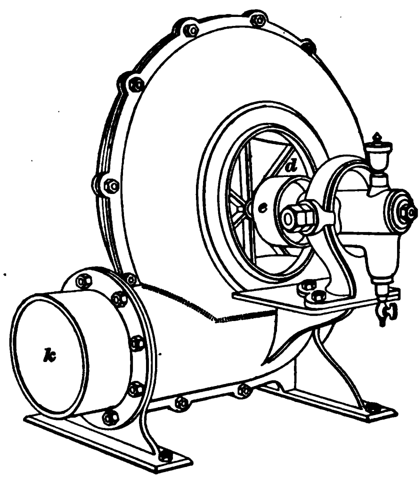


FIG. 7.

of 1 ounce to the square inch is equal to a pressure of 1.73 inches by the water gauge.

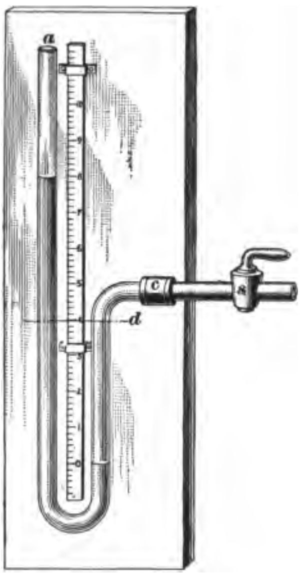


FIG. 8.

31. Water Gauge.—A simple form of water gauge can be made by bending a glass tube into the shape shown in Fig. 8. The tube is fastened to a board, and a scale graduated in inches is made to slide vertically between the two parallel arms of the tube. The air pipe is connected at *c* and has a stop-cock at *s*; the end *a* is left open. Water is poured into the tube until it rises to the height *d* in both tubes. The stop-cock *s* is then opened and the pressure forces the water up in the tube *a*; the scale is then moved into position so that the zero mark is on a line with the water in the shorter tube, and the reading taken to the height of water in the long arm.

THE ANVIL.

32. Construction of Anvil. — The ordinary blacksmith anvil is shown in Fig. 9; it has a horn *a* on one end, around which the bending is done. The body of the anvil is generally made of wrought iron, and a face of steel is welded on top and hardened under a flow of water to the proper degree of hardness. If too soft it will nick, and if too hard it is liable to chip at the corners and edges. Some anvils are made of cast iron and have a cast-steel face. These are very brittle. A cast-iron anvil with a horn cannot be used for heavy work because the horn is liable to be broken off. For light work, however, it will give

good service. Square-faced anvils without a horn are frequently made of cast iron, but the edges are liable to chip off.

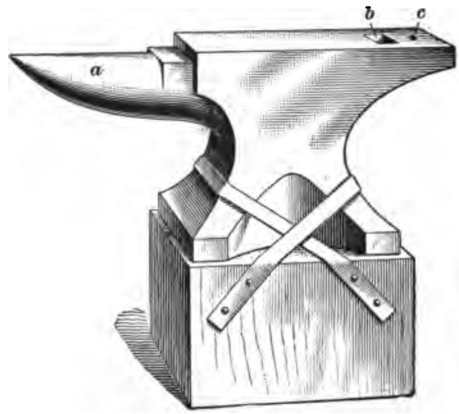


FIG. 9.

33. Setting of Anvil.—The anvil should be placed on a solid block (a butt end of oak is best) and be fastened to it with iron straps as shown in Fig. 9, or with staples. Anvils upon which soft metals are to be worked often have a layer of felt or cloth beneath them. The weights of anvils vary greatly; small ones are used for light work and large ones for heavy work. An average anvil will weigh from 150 to 200 pounds. The height of an anvil should be such that when standing beside it the knuckles will just reach the face of the anvil. The weight is generally stamped on the side, and on many anvils is given in gross weight. If a person stands facing the anvil, with the horn to the right, the weight is generally found stamped on the near side; the figures toward the left designate the number of hundredweight, in gross weight of 112 lb., the figures in the center the quarters of a hundredweight, and the figures at the right show the number of extra pounds. Thus, if an anvil is stamped 2–2–17, it means: 2 hundredweight of 112 pounds each, which is 224 pounds + 2 quarters of a hundredweight, which is 56 pounds + 17 pounds, making the total weight of the anvil 297 pounds.

At the right-hand end of the anvil, there is a square hole *b*, Fig. 9, called the *hardie hole*, in which cutting and forming tools are held. The small round hole *c* near the hardie hole is called the *pritchel hole*. In punching small holes, the core is punched out through this hole.

HAMMERS AND SLEDGES.

34. Classification.—Hammers are classified according to weight into *hand hammers*, *hand sledges*, and *swing sledges;* and according to the peen into *ball-peen*, shown

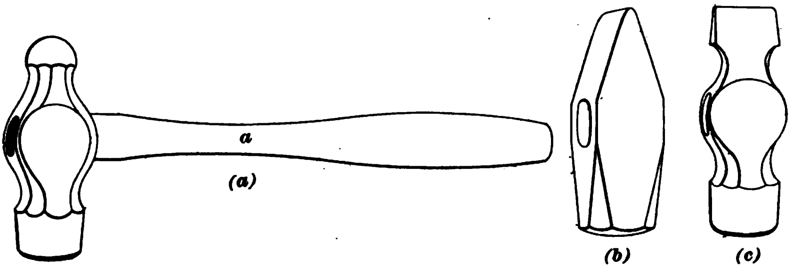


FIG. 10.

in Fig. 10 (*a*), *cross-peen*, shown in Fig. 10 (*b*), and *long-peen* or *straight-peen*, shown in Fig. 10 (*c*).

35. Hand Hammers.—A hand hammer should not weigh more than $2\frac{1}{2}$ pounds, a 1-pound hammer being a very convenient size for small work. The hand hammer is made to use with one hand and is handled by the smith himself. The handle is from 14 to 16 inches long, and is made of a size that will fit the hand comfortably. Near the head, the handle is made a little thinner, as shown at *a*, Fig. 10 (*a*). This is done to give it spring, to avoid stinging the hand. A handle that does not fit the hand is apt to tire or cramp the hand.

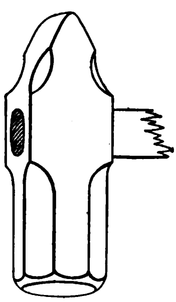


FIG. 11.

36. Hand Sledges.—A hand sledge, shown in Fig. 11, is a little larger than the hand hammer. It weighs from 5 to 8 pounds, and is used by the helper, who holds it with both hands. The handle is from 26 to 34 inches long, and not so slender, in proportion, as the handle of the hand hammer. In striking with the hand sledge, the helper holds it in both hands and strikes a shoulder blow, that is,

he raises the head of the sledge to the shoulder and strikes from this position.

37. Swing Sledge.—The swing sledge, one form of which is shown in Fig. 12, weighs from 8 to 20 pounds, or more. The handle is about 3 feet long. In using the swing sledge, the helper grasps the handle near the end with both hands, and strikes a full-arm-swing blow. This is for striking a heavy blow. The swing sledge is also made in the form shown in Fig. 11.

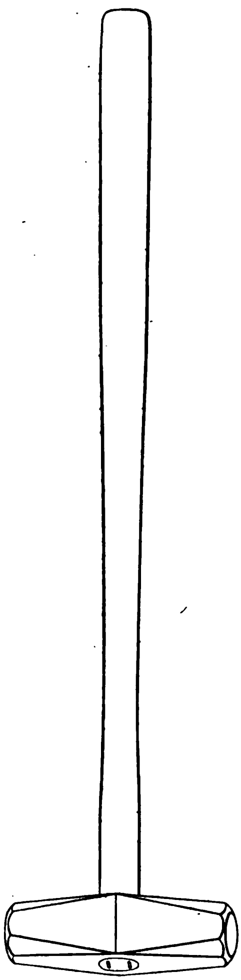


FIG. 12.

38. Ball-Peen Hammer.—The ball-peen, or chipping, hammer, shown in Fig. 10 (*a*), is a hand hammer that has the peen in the shape of a ball. The peen is used in riveting, or where it is required to stretch the metal in length and width, or for working in a hollow.

39. Cross-Peen Hammer.—The cross-peen hammer, shown in Fig. 10 (*b*), is used when it is required to stretch the metal lengthwise, but not crosswise. The cross-peen hand hammer is also used for riveting.

40. Long- or Straight-Peen Hammer.—The long-peen or straight-peen hammer, shown in Fig. 10 (*c*), is used when the metal is to be spread sidewise.

The hammers are made of different weights, and are selected to suit the work and the strength of the smith; a good set of hand hammers consists

of a 1-pound ball-peen, a $1\frac{1}{2}$-pound straight-peen, and a 2-pound cross-peen hammer.

41. Material Employed for Hammers.—Hammers were formerly made of iron or mild steel and faced with tool steel. If the whole head is made of tool steel, it is liable to chip and crack, but with a soft backing this is avoided to a great extent. Hammers made entirely of a special cast steel, called hammer steel, are much used and give good satisfaction.

42. Hammer Handles.—Care should be taken to see that hammer or sledge handles are perpendicular to the head, so that the blow will fall square and flat, and not on an edge. The handle should be well formed, elliptical in section, and a little thinner toward the head. It should be made permanent, not a makeshift affair, for the smith as well as the helper soon accustoms himself to the hammer, and when used to it knows just what effect a blow will have. A loose hammer head is dangerous.

SET HAMMERS.

43. General Description.—Besides the hammers mentioned above, there are **set hammers,** which, by their shape, help to form the iron into some desired shape or to localize the effect of the blow. The smith holds the set hammer down against the iron while the helper strikes the top of the set hammer with the sledge.

44. Square Set Hammers.—The square set hammer, shown in Fig. 13 (*a*), is used to produce a flat surface, or to make a square shoulder or offset.

45. Flatter.—The flatter, shown in Fig. 13 (*b*), is used like the square set hammer, the distinction between the two being that the flatter has a larger surface. For this reason, the flatter is used to flatten down a surface in

finishing, while the square set hammer is preferable when a square shoulder is to be made and the iron well driven down.

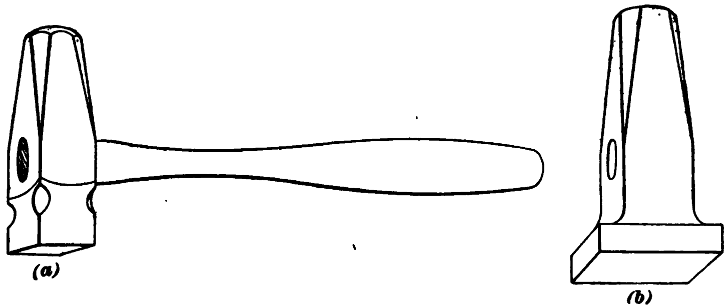


FIG. 13.

46. Fuller.—The fuller, shown in Fig. 14 (*a*), is used in *spreading out* the iron. On account of its shape, the fuller concentrates the force of the sledge blow upon a small surface, and, therefore, makes it more effective at that place.

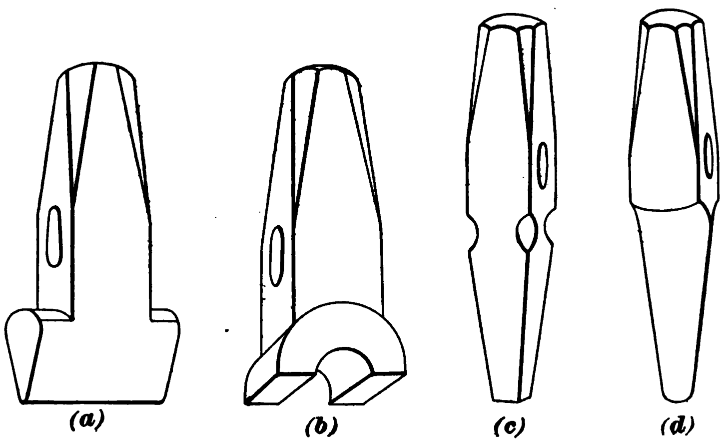


FIG. 14.

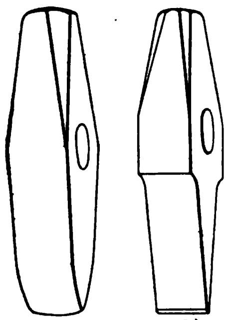
The fuller spreads the iron at right angles to the working edge. Its action is the same as that of the cross-peen or long-peen hammer. It is also used for hollowing out work and for forming a shoulder before drawing out.

47. Swage.—The swage, shown in Fig. 14 (*b*), is used for rounding iron, each swage being made for some certain

size of round iron. An assortment of three or four swages is generally kept on hand.

48. Punches.—Fig. 14 (*c*) shows a square punch, and Fig. 14 (*d*) shows a round punch. The punch is tapering, being small at the point and increasing in size toward the back. The hole is punched through the iron by driving the punch down into it. The hole is then stretched by driving the punch through the work until the required size is obtained.

49. Cutters.—A cold cutter is shown in Fig. 15 (*a*), and a hot cutter in Fig. 15 (*b*). The cold cutter is heavy and strong and is ground to a blunt edge so as to hold its edge in cutting cold iron. The hot cutter is drawn out thin and the edge is sharper than that of the cold cutter. The cold cutter cuts, and at the same time wedges the edges of the cut apart, while the other makes the cut as small as possible so as not to batter up the cut ends. The cold cutter is used to nick the iron all around, so that it can be broken.

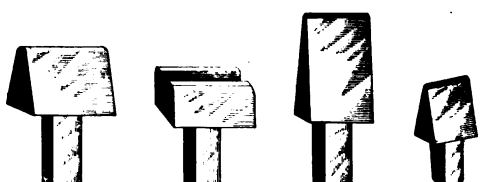


(a) (b)

FIG. 15.

ANVIL TOOLS.

50. Similarity to Set Hammers.—There are a number of tools made to fit into the hardie hole that correspond in shape to the set hammers. The results obtained with them are similar to the results obtained with the corresponding set hammer.



(a) (b) (c) (d)

FIG. 16.

51. Bottom Fuller. — Fig. 16 (*a*) shows a bottom

fuller, which, like the top fuller, is intended to spread or stretch the iron. The shank of the fuller fits in the hardie hole of the anvil.

52. Bottom Swage.—Fig. 16 (*b*) shows a bottom swage with a single groove. Bottom swages are frequently made with two or three grooves of different sizes in the same block.

53. Hardies.—The hot hardie is shown in Fig. 16 (*c*), and the cold hardie in Fig. 16 (*d*). They correspond in shape to the hot and cold cutters, the hot hardie being slender and having its edge ground to an acute angle, suitable for making a sharp cut, while the cold hardie is thicker and has an edge ground blunt so as to adapt it for nicking and wedging the cut apart.

54. Heading Tool.—The heading tool, shown in Fig. 17, is used in forming heads on the ends of rods, bars, bolts, and similar work. The hole through the head may be circular or square. There should be an assortment of these heading tools on hand to fit the various sizes of iron bars.

FIG. 17.

TONGS.

55. Kinds of Tongs.—There are many kinds of tongs in use for holding variously shaped pieces of iron. A few of the most common kinds are mentioned below. Special tongs are made to fit special cases, and it is frequently necessary to make a new pair or to alter a pair to fit some oddly shaped piece of iron.

56. Parts of Tongs.—The front part of the tongs *a*, Fig. 18 (*a*), which holds the iron, is called the *jaw*, and the handles *b*, Fig. 18 (*a*), are sometimes called *reins*. An elliptic ring *a*, Fig. 18 (*d*), called the *coupler*, is frequently slipped over the handles to hold the work tight, and thus relieve the hand from the strain.

57. Flat Tongs.—Fig. 18 (*a*) shows a pair of flat tongs used for holding flat iron. The tongs should always come together close against the piece of iron so that the jaws are parallel, thus having a good bearing when holding the piece.

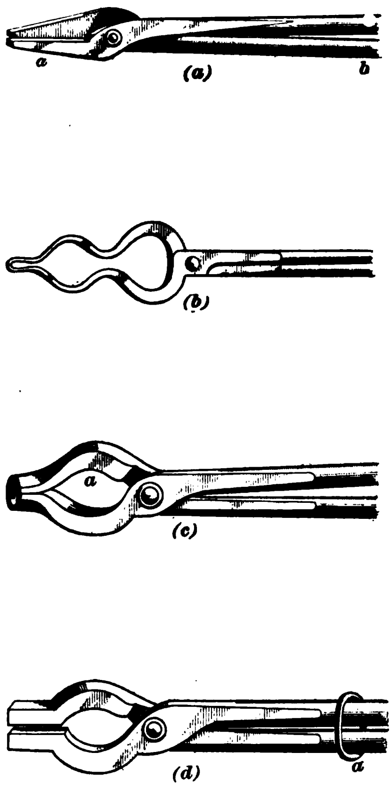


FIG. 18.

58. Pick-Up Tongs. Fig. 18 (*b*) shows a pair of pick-up tongs used for picking up pieces of iron, also for holding small pieces while tempering, etc. The jaws are bent to give them spring, and the front bend is convenient for holding round iron.

59. Bolt Tongs.—Fig. 18 (*c*) shows a pair of bolt tongs. They are made for holding round iron, and have a *pocket a* for the head of the bolt.

60. Gad Tongs.—The gad tongs, shown in Fig. 18 (*d*), are used for holding flat or wedge-shaped pieces that have a head or large end.

61. Care of Tongs.—The tongs should always be hung on a rack to keep them handy and avoid their being mislaid. The tongs should not be left in the fire if it can be avoided. When the jaws become hot, they will bend apart and must be bent back before they can be used again, and besides, they must be dipped into the water, and this constant dipping spoils the iron and makes it brittle.

AUXILIARY TOOLS.

62. Dies.—Dies are tools used for forming iron into certain shapes. The set hammers and anvil tools tended in this direction, but the die is a block of iron or steel cut out

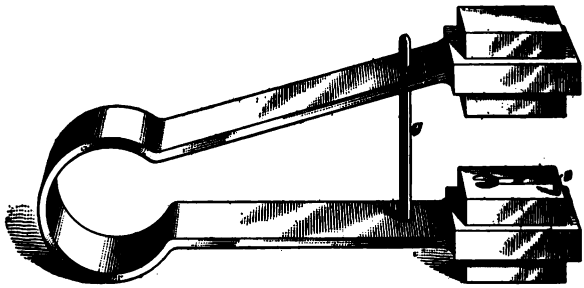


FIG. 19.

in such a way that the iron may be pressed or hammered into it, and thus take the shape of the hole. For convenience, the two blocks are often set into frames connected by a spring, as shown in Fig. 19. This holds the two blocks in position and separates them as soon as the hammer is raised from the die. A dowel-pin *s* may be put into the die or a guide *g* put on the handles, as shown; either one will insure that the die blocks meet properly. Dies are generally used under a steam or power hammer, though some small dies are made for use on the anvil. Such dies are really only special swages.

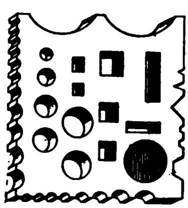


FIG. 20.

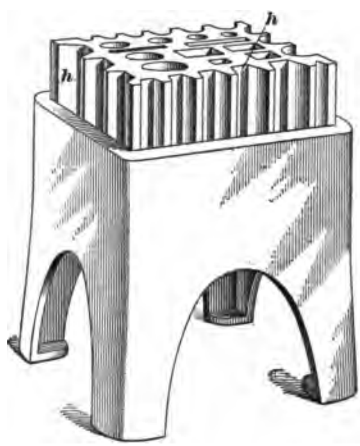


FIG. 21.

63. Swage Blocks.—Figs. 20 and 21 show two forms of swage blocks. These blocks have variously shaped grooves and holes cut into them, and are used like a swage, or as a heading tool, and for similar work. They are really simple forms of dies. Fig. 21 shows a swage block on a stand. The grooves *h*, *h* in the edges are used for forming hexagonal heads and nuts of various sizes.

THE VISE.

VISE AND BENCH TOOLS.

64. Description of Vise.—The vise is a tool in which the work is held securely for bending, twisting, chipping, filing, etc. The blacksmith's vise shown in Fig. 22 is of the design called the *leg vise.* The leg rests on a solid block on the floor, while the body is secured to the bench with bolts through the strap *s*. The vise is made of wrought iron and has hardened-steel jaws. The screw has a square thread and should be oiled occasionally. The top of the vise should be set at elbow height; this will be found most convenient for filing and chipping.

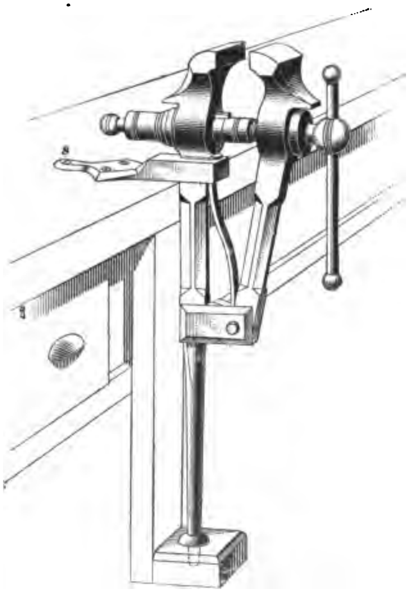


FIG. 22.

65. Copper Jaws. A very necessary part of the vise is a pair of copper jaws. These are made of heavy sheet copper, Fig. 23, formed to fit over and between the jaws of

the vise. They protect the work from being bruised by the steel jaws as would be the case if it were clamped between the bare jaws. Besides this they protect the jaws of the vise, for it is often necessary to clamp hot pieces of iron in the vise. This would draw the temper out of the jaws if they came in direct contact with it. To make them more efficient for this purpose, pieces of asbestos paper are kept on hand, which fit over the vise jaws inside the copper jaws.

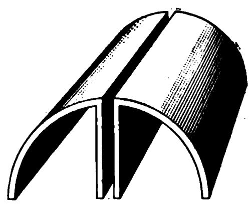


FIG. 23.

This makes the insulation very good, and besides protecting the steel jaws, prevents the rapid cooling of the hot iron by contact with the cold vise. Sheet-iron jaws are often used for hot work.

FIG. 24.

66. Surface Plate.—The surface plate is a plate of cast iron $1\frac{1}{2}$ inches or 2 inches thick, planed smooth on the top side. This is used for testing work, to see whether it is straight, and to detect warp or wind. It is also very useful in laying out work. The surface plate is generally placed on a small, strong bench so as to be accessible from all sides, as shown in Fig. 24. It should be carefully leveled and then secured in position. This makes it possible to

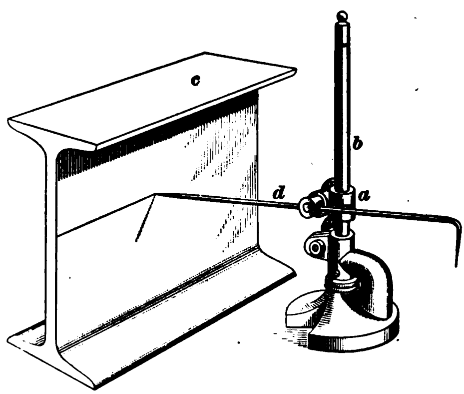


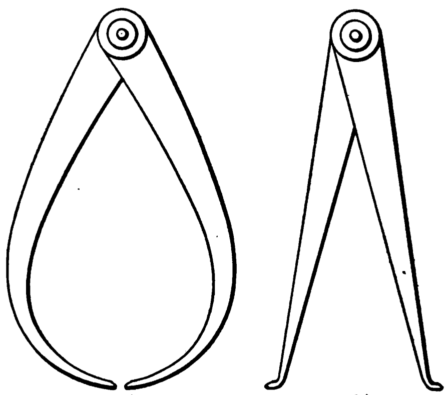
FIG. 25.

test work on it by means of a level. Large surface plates are ribbed on the back to make them stiffer.

67. Surface Gauge.—Fig. 25 shows a surface gauge that is used to scribe a line on the piece *c*. This tool is used on the surface plate to draw or scribe lines parallel to the surface of the plate. The sliding collar *a* can be set at any height on the vertical standard *b*, and the needle *d* can be clamped in any position on this collar.

68. Taps and Dies.—A set of taps and dies for bolt sizes from $\frac{1}{4}$ inch to 1 inch and a stock with which to use them will be found useful for cutting threads of bolts and nuts.

69. Calipers.—Calipers are used for measuring diameters, widths, and thicknesses. Single calipers are made of two pieces of sheet steel bent to the required shape and put together with a rivet. They are made to work rather



(a) (b)

FIG. 26.

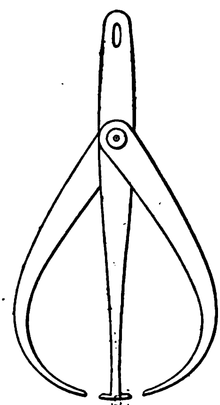


FIG. 27.

stiffly so as to remain wherever set. Fig. 26 (*a*) shows a pair of outside calipers, and Fig. 26 (*b*) shows a pair of inside calipers. Fig. 27 shows a pair of double calipers with which two sizes can be taken at one time, as, for instance, the width and thickness of a forging.

70. Dividers.—The dividers, shown in Fig. 28, are used for measuring the distance between two points and for describing circles. The points are clamped by means of a thumbscrew *t*, which sets against the wing *w*, and the finer adjustments are made by means of the thumb nut *m*. The points are held apart by means of the spring *s*.

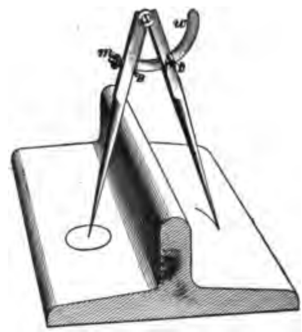


FIG. 28.

FIRE AND OTHER TOOLS.

71. Fire Tools.—The following fire tools should be provided for each forge: A poker, Fig. 29 (*a*), which is a rod of iron about $\frac{1}{2}$ inch in diameter and 20 inches long, with a handle at one end; the fire hook, Fig. 29 (*b*), which is

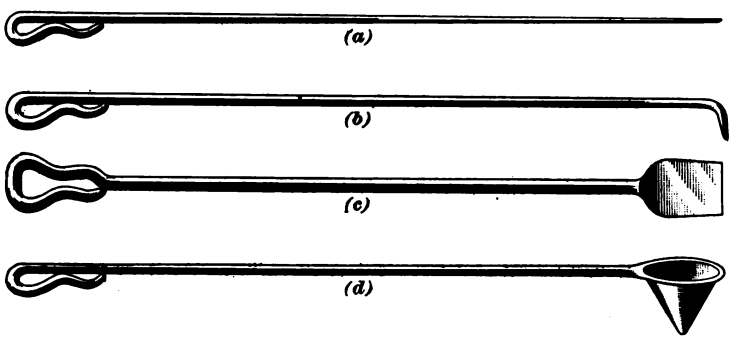


FIG. 29.

similar to the poker, but has a hook bent on one end; the shovel, Fig. 29 (*c*), has a sheet-iron blade and a long handle; the sprinkler, Fig. 29 (*d*), consists of a funnel-shaped piece of tin with a small hole in the bottom, fastened to an iron rod for a handle.

FIG. 30.

This is used for cooling parts of a piece of iron and for

keeping the fire from spreading. The ladle, Fig. 30, is used for melting soft metals, fluxes, etc.

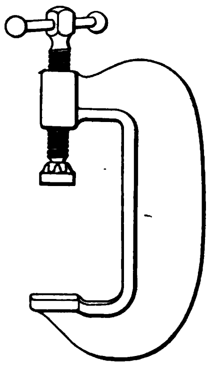


FIG. 31.

72. Marking.—A piece of soapstone or a soapstone pencil is generally used for marking iron. Soapstone marks will not burn off and are plainly visible when the iron is hot. If pieces of iron or steel are to be cut off they may be marked by nicking with a chisel, cutter, or hardie.

73. Other Tools.—Several monkey-wrenches of assorted sizes, and several horseshoe or **C** clamps, like that shown in Fig. 31, should be provided.

THE FIRE.

74. Starting and Maintaining the Fire.—A good way to start the fire is to heap coal all around the tuyere to a depth of 2 or 3 inches, leaving the tuyere free. A handful of shavings or some oily waste is set on fire and put into the pit over the tuyere, and a small quantity of fuel spread over it. The blast is turned on very lightly, and as the fire burns up, more fuel is added. If coal is used for fuel, it is well to coke a quantity of it before putting the iron into the fire. The fire is kept from spreading by sprinkling water around the edges. The fire should not be allowed to burn too low, because this makes it necessary to place the iron nearer the tuyere and brings the hot iron too near the cold blast. For this reason, the blast must always have a good bed of fire to pass through before coming in contact with the iron that is being heated. The hot iron should not come in contact with fresh coal, but the loss by combustion should be replenished by bringing coke from the top and sides of the fire toward the center, and adding the fresh fuel on the outside of the heap, where it can coke slowly. The fire must

always be kept clean, all cinders, ashes, scraps of iron, etc., being removed.

A conical block of wood is sometimes used to build the fire. The block is put over the tuyere with the small end down, and the coal packed about it. The block is then taken out and shavings put into its place, and the fire started.

75. Classification of Fires.—The fire may be maintained either *open* or *hollow*. In the open fire, the combustion takes place on top of the heap over the tuyere; while in the hollow fire, a section of which is shown in Fig. 32, the combustion takes place inside, the top being

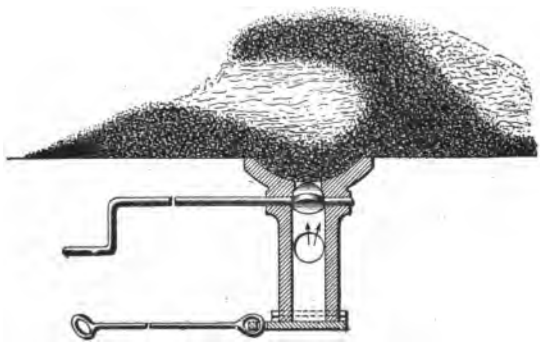


FIG. 32.

roofed over with coke and coal. A hole is left in front for the iron. This form of fire is much hotter, as the hot roof radiates heat as well as the hot sides and bottom. It also heats the iron more evenly and lessens the chilling by contact with the outside air.

76. Holding the Fire.—If the fire is not to be used for some time, it may be held by putting a stick of hard wood into the fire and pounding the fuel down around it. The blast is then turned on gently for a few moments to liven it up well. After this, it may be left without a blast for an hour or more, and can be restarted by turning on the blast until well kindled. The ashes and cinders are then raked out, blown out with the blast, or dropped through the tuyere into the cinder pit.

HEATING AND ITS EFFECTS.

77. Names of the Different Heats.—If the end of a bar of ½-inch round iron about 2 feet long is heated, it can be made to pass through all the different stages from normal temperature to a burning heat. If the heating is done slowly, the different heats can be watched and noted. After it has been in the fire a short while, the iron will be found to be just hot enough to show its heat in a dark place, as under the forge or in the hood. This is called *black hot* or *black red*. If it is put back into the fire and the heating continued a little longer, it will become hot enough to show its heat by the light of the forge or in daylight; this is designated as *dull red*. If it is heated more, it becomes *bright red* or *cherry red*, and if it is heated still more, so that it begins to throw sparks, it is known as *white hot*. After this it begins to burn; sparks fly off in great numbers and drops of molten iron fall from it; it has been overheated or *burned*. By letting a piece of iron pass through these various heats the eye will learn to recognize them.

78. Hammering Iron While Hot.—If the iron, while *burning*, is brought from the fire and laid upon the anvil, and the heated portion hammered vigorously for a while, the end will crumble and fly off; but a little distance back from the end it will flatten, while a little farther back from this, at the end of the heat, it will not flatten very much. If the hammering is continued until the iron is black hot, but no longer, the end will have been drawn out in the form of a wedge.

79. Hammering Cold Iron.—If the piece is allowed to cool off and is then hammered immediately back of the wedge, keeping it round but reducing it in size, it will become hot. This shows that hammering heats the iron. The faster the blows fall, the hotter it will become. For this reason, hot iron should always be worked as rapidly as possible, to get as much benefit from the heat as possible,

and to produce heat to counteract the chilling effect of the cold hammer and anvil.

80. Results.—When cold, the piece presents an interesting appearance. At the end where it was burned it will be found to be cracked and ragged; back of this it is covered with scale; then comes a clear, smooth part extending back to the round part. This shows that the bright-red heat is the best heat to work iron at, stopping when black hot. Iron is sometimes hammered below a black heat in order to give it a smooth, glossy surface. This tends to stretch the outer surface of the metal and thereby often causes it to scale off or blister. Besides this, in small work, the fibers of the iron are very liable to become separated at the center of the piece and thus make the work defective. This can seldom be detected on the outside, but by bending the piece in a vise until it breaks, the effect of cold hammering becomes very plainly visible.

If the piece that has been hammered cold is put into the vise and bent to and fro until it breaks, the probabilities are that it will sliver and crack before it breaks off, because the fibers have been separated by hammering it cold. At this point it is well to examine the grain, for much of the nature of iron can be learned from the appearance of the grain. If the piece broken off is clamped in the vise and tried with an old file, it will be found that the point of the wedge is very hard, a little farther back it has a hard scale that can be scraped off, and below this the iron is soft; back of this the iron is soft, but where it has been hammered cold there is a hard scale much like that caused by burning the point.

WORKING FORCE.

81. Single-Hand Work.—On light work, the smith often works alone at the fire; especially when his work does not require the use of set hammers, which necessitate the help of a striker.

82. The Helper.—When the work is light, one helper strikes for several smiths. The smith that wants the helper rings his hammer on the anvil to call him. When not striking for one of the smiths, he has some floor or bench job to go back to. Ordinarily, however, every smith has a helper. The helper does the striking and works the bellows or the hand- or foot-power blower if the blast is produced by such means. He starts the fire and looks after the tools. When a smith has very large work, he frequently has several helpers to strike for him; besides this, it often requires one or more to help him handle the iron. When a smith has several helpers, the one that attends to the fire or furnace is called the **heater.**

In handling iron in a hot fire, smiths frequently dip their hands and arms into water before approaching the fire. The evaporation of the water keeps the arms cool, and thereby makes it possible to approach closer to the fire than would be possible if the arms were dry.

83. Cones or Tapered Mandrels. — For forming rings and eyes, the cone or tapered mandrel shown in Fig. 33 is used. It is made of cast iron and may be in a single piece or the upper portion of it may be separate and secured to the lower portion by a pin on the upper portion which fits a socket in the lower portion. The main body *a* is given a plain smooth taper. Most cones are provided with a groove *b* at one side, which enables the smith to grasp the work with a pair of tongs while it is on the cone; or in the case of a ring attached to a chain or an eye on a ring, the link or eye is taken care of by the groove *b*. The upper end *c* is from 2 to 3 inches in diameter, depending on the size of the cone, and the lower end ordinarily varies from 10 to 14 inches.

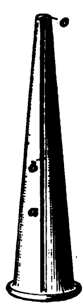


FIG. 33.

BLACKSMITHING AND FORGING.

(PART 2.)

FORGING OPERATIONS.

EXAMPLES OF FORGING.

1. General Consideration.—Operations that are in constant use in blacksmithing and that are necessary in most jobs will now be described. For this purpose, specific cases are taken to illustrate the methods; but it must be borne in mind that the same methods can be applied to all similar work with the modifications in dimensions and such other features made necessary by the special case in hand.

DRAWING.

2. Round Drawing.—Drawing is the process of stretching a piece of iron in one or two directions. Drawing a bar of round iron out to a smaller diameter is probably one of the easiest forms of drawing. If a bar is to be drawn out, the portion to be drawn is marked with the soapstone and then heated carefully to a bright-red or to a welding heat. While the iron is being heated, the calipers are set to the required size. When the bar is hot, it is taken from the fire with the left hand, holding it by the cold end, and quickly brought to the anvil. The end is hammered rapidly, turning it a little after each blow and keeping it as

nearly round as possible. If necessary, a second heat is taken and the piece finished with the hand hammer or with a swage, as shown in Fig. 1. In drawing out a piece of iron, it is well to turn it from left to right and then from

FIG. 1.

right to left, because turning it in the same direction continually is liable to twist the fibers into a spiral. If the iron is to be reduced much in size, it should be drawn square first, then octagonal, and then rounded up with a hand hammer or with a swage.

3. Face of the Anvil Constructed for Drawing.—The face of the anvil is straight lengthwise, as shown from *a* to *b*, Fig. 2, but it is slightly crowned crosswise from *a* to *c*, as shown somewhat exaggerated. If the face of the anvil were perfectly flat, a straight piece of iron would

show a tendency to curl upwards while being worked, and unless it was held perfectly flat on the anvil it would sting the hand, and, besides, there would be danger of nicking it where it rests on the edge; with a face crowned in one direction, however, this is avoided. Besides this, hammering a piece of iron on the crowning face localizes the effect of the blow and acts to a certain extent like the bottom fuller.

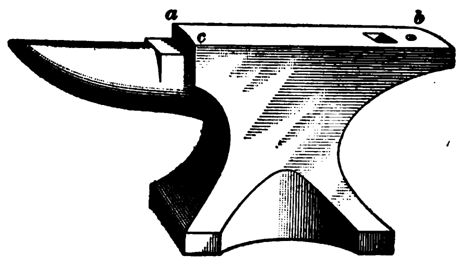


FIG. 2.

If a piece is to be drawn lengthwise, it should be held across the face of the anvil, as shown in Fig. 3, whereas if it is to be spread in width, it should be held lengthwise on the anvil, as shown in Fig. 4. If a rod is to be straightened, it should be laid lengthwise, as shown in Fig. 4, because the anvil is straight in this direction.

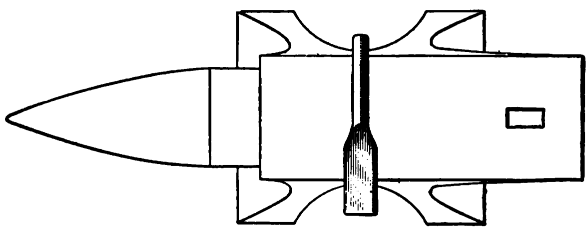


FIG. 3.

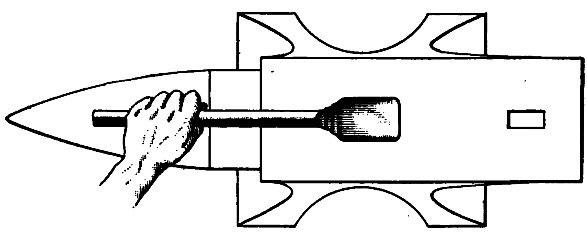


FIG. 4.

FORGING A STAPLE.

4. Preparation of Stock.—If a staple such as is shown in Fig. 5 is to be made out of a piece of $\frac{1}{2}$-inch round iron, the required length is first marked off on the bar. In drawing $\frac{1}{2}$-inch iron down to $\frac{1}{4}$ inch, it will draw out to 4 times the original length. To make 5 inches of $\frac{1}{4}$-inch round iron will therefore require $\frac{1}{4}$ of 5 inches, or $1\frac{1}{4}$ inches of $\frac{1}{2}$-inch round iron. A distance of $1\frac{1}{4}$ inches is therefore marked off from the end of the $\frac{1}{2}$-inch bar, and drawn out to $\frac{1}{4}$ inch round. When it is nearly down to the required size, it is heated a second time, and finished to the exact size, using the swage as shown in Fig. 1, and trying it with the calipers in order to make sure of the size.

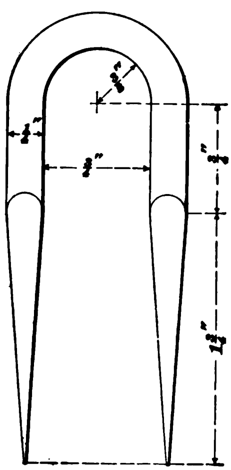


Fig. 5.

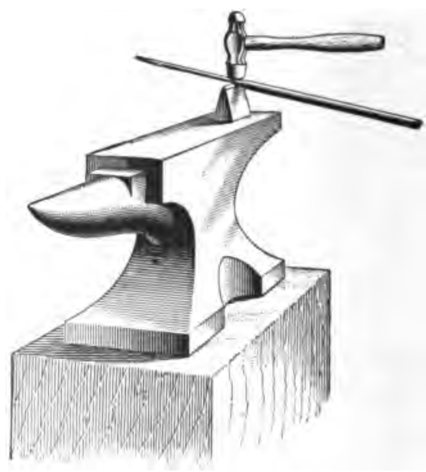


Fig. 6.

5. Forging.—The $\frac{1}{4}$-inch round end will now be about 5 inches long. On this, a distance of 1 inch from the end is marked off, the end heated, and drawn out to a square point $1\frac{3}{4}$ inches long. This piece is then cut off from the bar, using the hardie as shown in Fig. 6, and making the piece $5\frac{1}{2}$ inches long, over all. The other end is marked and drawn out to a point the same as the first, keeping both squares in line. The piece will now be about $6\frac{1}{4}$ inches

long, $\frac{1}{4}$ inch round in the center, with a square, tapering point $1\frac{3}{4}$ inches long at each end. The center of the piece is then marked and heated, and the piece bent over the horn of the anvil to the shape shown in Fig. 5, making the distance between the two straight, parallel ends $\frac{3}{4}$ inch. In bending over the horn of the anvil the piece is held against the large part of the horn and bent by light hammer blows, turning it to keep it round; then while hammering it the piece is gradually brought toward the point of the horn. When bent, the curve should be uniform and the two ends of the same length. If it is warped or twisted, it is flattened on the anvil with the flatter shown in Fig. 13 (*b*), *Blacksmithing and Forging*, Part 1.

SQUARE DRAWING.

6. Holding Work and Striking Blows.—In round drawing, the iron is turned a very little at a time, so as to bring all points under the hammer. In square drawing, however, the iron must always be turned quarter or half way around. This requires some practice, as the least variation in the amount of the turn will bring the piece out of

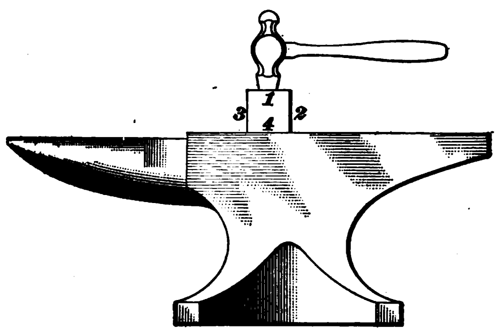


FIG. 7.

square. In drawing a square bar down to a square of smaller size, the sides of the original bar help to guide the hand in making the proper amount of turn, but if a round bar is to be drawn down to a square, the amount of turn must be

entirely governed by the hand and the eye without anything to guide it or to give opportunity for comparison.

In drawing down a square bar to a square of smaller size, the piece is heated and brought to the anvil, holding one of the faces down flat and striking blows square upon the top face, drawing it down along its entire length. It is then turned quarter way around and the top side hammered until the piece is about square. The opposite face is then turned up and hammered and finally the last face is brought under the hammer. The figures *1*, *2*, *3*, *4* in Fig. 7 show the order in which the faces are brought under the hammer.

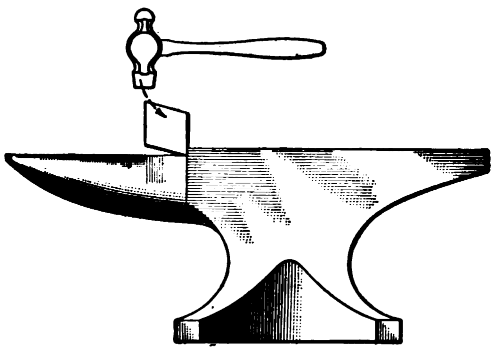


FIG. 8.

This method of turning the work lessens the liability of getting the piece twisted or diamond-shaped, as shown in Fig. 8. If it shows a tendency in this direction, it can easily be remedied by a few judicious blows, holding it as shown in Fig. 8. If desired, the piece can be finished under the flatter. It is held on the anvil lengthwise and the flatter held against the upper face parallel to the face of the anvil, while the helper strikes a few light blows.

FORGING A GATE HOOK.

7. Forging.—If a hook like the one shown in Fig. 9 is to be made out of a bar of ½-inch square iron, the operation will be about as follows. As it will take about 4 inches of

½-inch square stock to make the hook, a distance of 4 inches is marked off from the end. This portion is heated and drawn out until it calipers ⅜ inch square, which will make it about 5½ inches long. A distance of 1¾ inches is then marked off from the end and drawn out to $\frac{5}{16}$ inch round, keeping one side straight, as shown at *d*, Fig. 10. The shoulder or offset *f* is formed over

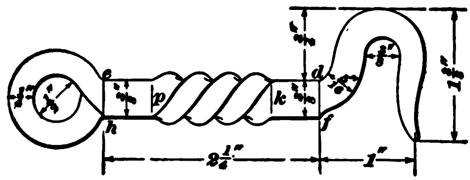


FIG. 9.

FIG. 10.

the sharp edge of the anvil, as shown in Fig. 11. By striking the upper side with the hammer, as shown, the top will remain straight at *d*, after which it can be finished with the swage to make it perfectly round. A distance of ¾ inch is then marked off on the $\frac{5}{16}$-inch end and the point drawn down round, as indicated by the dotted lines, Fig. 10. The entire piece is then cut off from the bar and the other end of the ⅜-inch square marked off, making the distance between the shoulders 2¾ inches, and drawn to ¼ inch round, as shown in Fig. 10, keeping it straight at *e* and forming a shoulder at *h*. The ¼-inch round part is bent

FIG. 11.

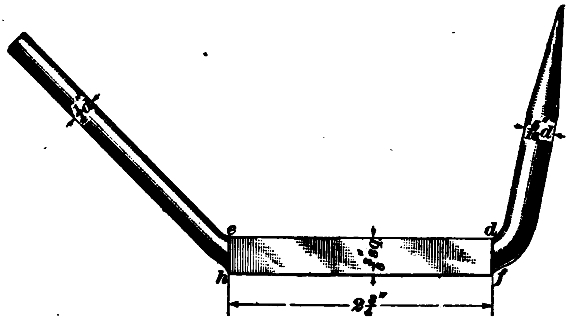


FIG. 12.

into a ring over the horn and the $\frac{5}{16}$-inch round end into the hook, as shown in Fig. 13.

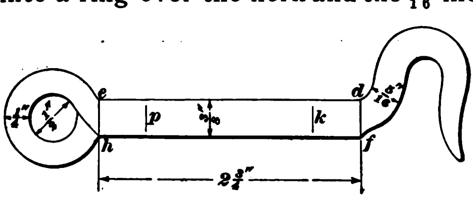


FIG. 13.

In bending the hook and the ring, the piece is held with one round end projecting over the farther edge of the anvil, and this projecting round end is bent back until it has the shape shown in Fig. 12. After both ends have been bent in this way, the ring and hook are bent over the horn of the anvil by light hammer blows.

8. Twisting. — Distances of ½ inch are now marked off on the square part from the shoulders *f* and *h*, giving the points *k* and *p*, Fig. 13. The portion between these marks *k* and *p* is then brought to an even heat and twisted. To do this,

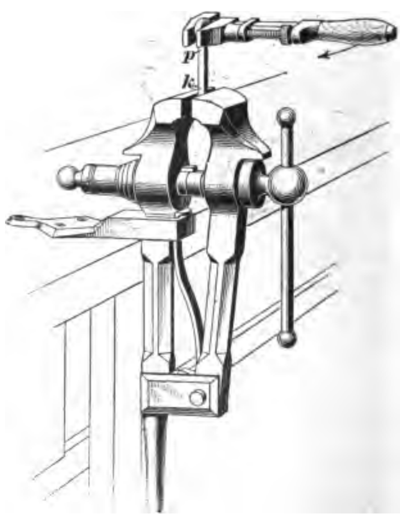


FIG. 14.

the piece is clamped in the vise vertically by the hook end, as shown in Fig. 14, with the point *k* at the top edge of the vise jaw, and the monkeywrench is clamped to the ring end immediately above the point *p*. The wrench is then given a complete turn, twisting the square part as shown in Fig. 9. If it has become bent it may be straightened by hammering it between two blocks of wood on the anvil so as to avoid battering the sharp edges.

UPSETTING.

9. Definition.—Upsetting is the term applied to the operation of increasing the thickness of a piece of iron by shortening it. In order to confine the heat to the portion that is to be upset, the rest of the bar is cooled by pouring water over it with the sprinkler. When sufficiently heated, the piece is brought to the anvil and upset by one of the following methods.

10. Ramming.—If the bar is from 2 to 3 feet long, and is to be upset at the end, the heated end of the bar is rammed against the face of the anvil, as shown in Fig. 15. The entire force of the blow is concentrated at the hot end of the rod, and, consequently, drives the particles of iron near the end together in the direction of the blow; this bulges the iron out where it is hot.

FIG. 15.

11. Upsetting With the Hammer.—If the bar is short it may be brought to the anvil with a pair of tongs, as shown in Fig. 16, and held vertically on the anvil with

the hot end up and the heated end hammered, or it may be held vertically on the anvil with the hot end down and the blows struck on top of the cold end. By the last method, the heated end is constantly in contact with the cold face of the anvil and will therefore cool very rapidly.

FIG. 16.

The result is that the bar will not flare and spread out so much, but the bulge will extend up a little farther than by the other methods. The same methods are used if the upset is to be made nearer the center of the bar.

12. Precautions.—In upsetting a bar, it frequently begins to bend after a few blows have been struck. If this occurs, the piece must be straightened at once, for any blows struck endwise on a bent bar will not have much effect in upsetting it, but will only bend the bar more and

make the straightening all the harder. For upsetting, a good heat is required; in fact, it is well to make the final heat a welding heat, because upsetting often separates some of the fibers, and by taking a welding heat over the piece and hammering it on the sides a little, these loose fibers will be welded together again.

MAKING A BOLT.

13. Forging.—If a ½-inch bolt, as shown in Fig. 17, is to be made out of a ½-inch iron rod, the end of the rod is heated and upset. When enough metal has been upset to form the head, the enlarged end is heated and the cold end of the bar passed through a suitable hole in the swage block, Fig. 20, *Blacksmithing and Forging*, Part 1, or through the heading tool, Fig. 17, *Blacksmithing and Forging*, Part 1, which is laid over the hardie hole so that the body of the

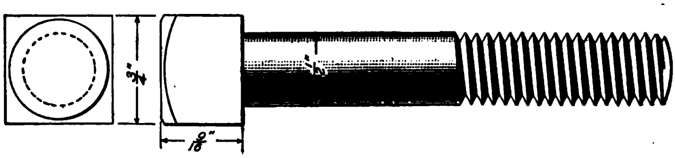


FIG. 17.

bolt passes through it. The iron is then hammered down against the swage block or heading tool, as shown in Fig. 18, until the head is $\frac{9}{16}$ inch thick. It is then driven out of the heading tool and the square head formed with the hand hammer. The bolt is then put back into the heading tool and the head finished. After this it is cut off to the desired length and the burrs hammered down. In the case of steel bolts, it is best to draw the bolt from stock large enough to form the head. The head of an iron bolt may be formed by upsetting or by welding on a ring.

14. Cutting the Thread.—When cold, the bolt is put into the vise and a thread cut on it with the ½-inch

die. The die is put over the end of the bolt squarely and given a turn under a steady pressure; when the thread is caught, the die is examined to see that it is on square. If it is, the thread is cut down about half a thread farther, to give it a good hold. Oil or soapsuds must then be applied to lubricate the die and wash out the chips. After this the thread is cut down to the depth of the die, which should

FIG. 18.

then be backed off and a standard nut tried over the thread to make sure of the size. If the nut fits properly, the thread is cut to the required depth, the die cleaned out, and the chips and oil cleaned off the bolt; this may be accomplished by rapping it with a stick of wood. When the nut does not fit, the die is adjusted, and another trial made. When the die is set right, the standard nut need not be tried on the next bolt.

ANGLE OR CORNER PIECE.

15. Stock Required.—If an angle like the one shown in Fig. 19 is to be made from a bar of ½-inch round iron, it will be found that the ½-inch round bar will draw out to ⅜-inch square easily, but there will not be enough stock to form a sharp angle. For this reason, the center must be upset to give the additional stock required for the corner.

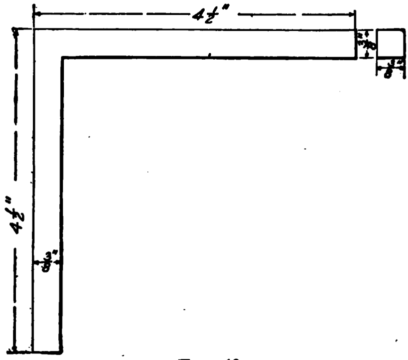


FIG. 19.

16. Forging. — It will require about 7 inches of ½-inch round iron to make the bracket. This is cut off and the center heated and upset to ⅝ inch diameter.

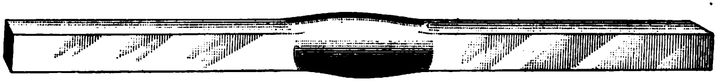


FIG. 20.

The two ends are then drawn out to ⅜ inch square, leaving the center large, as shown in Fig. 20.

17. Bending and Making Sharp Corner.—The piece is bent at right angles in the center by sticking one end through the hardie hole down to the heated center and then bending the other end down toward the anvil, as shown in Fig. 21. To make the corner sharp, the piece is held on the face of the anvil, as shown in Fig. 22, and the angle made true, making the iron ⅜ inch square. To do this, the hammer is drawn in striking the blow, as shown by the arrow in Fig. 22; this draws the iron toward the corner. The piece is then finished with the flatter and the ends cut off to an equal length on the hardie, and then squared with the hammer. The stock for the square corner may be obtained by bending the iron and then welding a wedge in at the corner.

UPSETTING, BENDING, AND PUNCHING A CHAIN HOOK.

18. Preparation of Stock.—If a chain hook, as shown in Fig. 23, is to be made from a bar of ½-inch round iron, the end will have to be upset to gain stock for the eye of the hook. If 1½ inches of the end is shortened to 1 inch, there will be enough to make it. For this a distance of 1½ inches is marked off from the end of a bar of ½-inch

FIG. 21.

round iron, 6½ inches long. This end is heated and upset as shown in Fig. 16, until the original 1½-inch length is shortened to 1 inch. This makes the piece 6 inches long. The piece is now flattened down to ⅝ inch in thickness, making the upset portion circular and about 1 inch in diameter, as shown in Fig. 24.

19. Forming the Eye.—In flattening the upset portion down to $\frac{3}{8}$ inch in thickness, it should be spread sidewise as much as possible. If it draws out in length, it may be upset a little in a swage or heading tool or it may be upset on

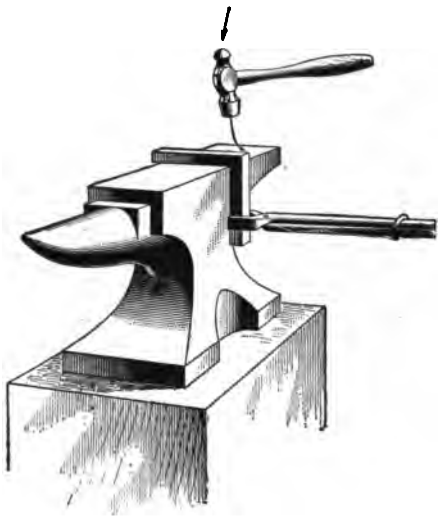


FIG. 22.

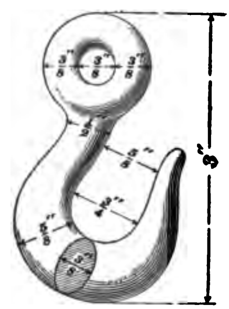


FIG. 23.

the edge of the anvil as shown in Fig. 25. When the head has been formed, it is heated and a $\frac{1}{4}$-inch hole put through with the punch, which should be kept cold by dipping it before and after punching the hole.

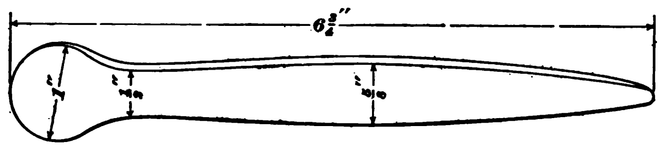


FIG. 24.

20. Punching Hole in the Eye.—The hole is first started, then the punch is held aside to see whether it is in the center; if it is, the punch is driven down well and the piece turned over and punched from the other side where the iron shows a black circular spot. The core is driven out through the hardie hole or through the pritchel hole.

In punching, some smiths prefer to put a little coal or coke dust into the hole after it has been started and then

finish the hole by driving the punch on top of the coal dust. This keeps the point of the punch cool and prevents it from sticking in the hole.

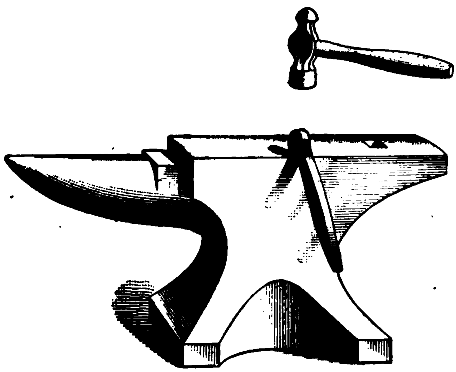


FIG. 25.

21. Finishing the Eye.—When the hole has been punched, the eye of the hook is raised to a welding heat and worked over to weld up any parted fibers or split places. For this, the punch is put into the hole and left there while hammering the eye. The punch is driven down occasionally to keep it tight; this will spread the hole to about $\frac{5}{8}$ inch in diameter.

22. Bending the Hook.—After this the corners are rounded and the hook bent into the required shape by holding it on the horn of the anvil and striking it with a light hammer.

FORGING ROD STRAPS.

23. Forging a Strap Without an Excess of Metal.—To make a rod strap of the form shown in Fig. 26 (*a*), select stock of the width shown at *a* in Fig. 26 (*b*) and deeper than *b* by a sufficient amount to form the corners shown at *b* in Fig. 26 (*c*). Draw this stock to the form shown in Fig. 26 (*c*), leaving the sides slightly thicker at *c* than they are required to be in the finished strap, as they will draw in the bending, and being careful that the hammer leaves no ridges, which would tend to start cracks, called *gaulds*, in the corners, that become deeper as the work progresses. Next, take the stock in the tongs, and, holding it as shown in Fig. 26 (*d*), proceed to bend it, using

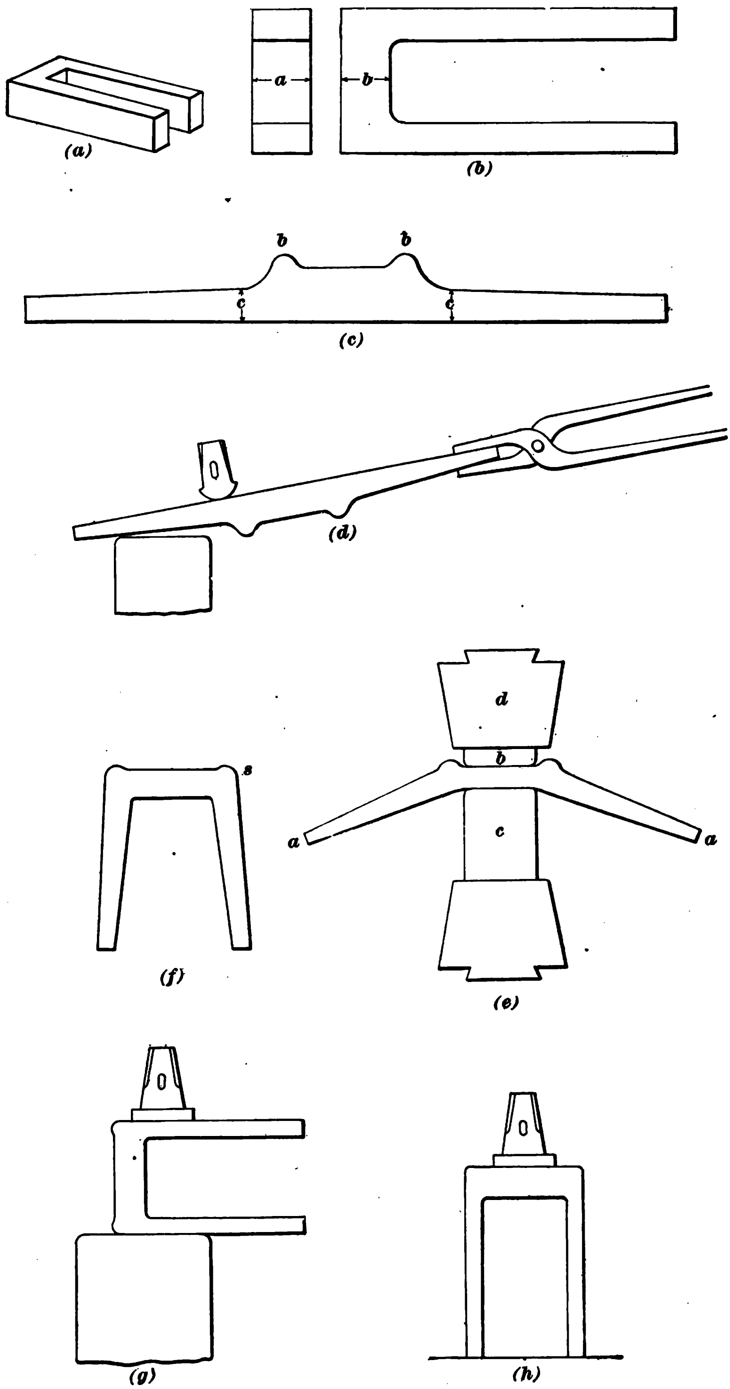
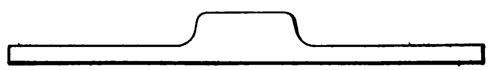


FIG. 26.

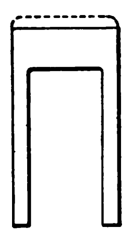
a large fuller to start the bend, as by starting in this way the iron is not cramped at the corners. Any ridges left by the hammer may be taken out with the fuller when starting the bend.

After the bends have been started as shown in Fig. 26 (*d*), place the stock in clamps, or hold it in the steam hammer in the manner shown in Fig. 26 (*e*). This may be done by lowering the upper die *d* on the upper one of the two blocks *b* and *c*, between which the stock is held, and holding it firmly by means of the steam pressure. Next, have two helpers, one on each side, strike simultaneously on the ends until the piece has the form shown in Fig. 26 (*f*). Take a heat on the corner by placing the side *s* down in the fire, and by using the flatter, bring the side to the shape shown in Fig. 26 (*g*), and repeat this on the other corner and side. It will be necessary during this operation to use the flatter on the strap, which is held as shown in Fig. 26 (*h*), in order to keep the crown of the proper shape.

24. Forging a Strap With an Excess of Metal and Trimming.—Another way to make the strap is to use



(*a*)



(*b*)

FIG. 27.

wider stock and to bring this up to the form shown in Fig. 27 (*a*). The sides are bent in the same manner as in the operation just described, and the strap brought to shape as before. The end is formed, however, by cutting off the

excess of stock that has been allowed there, as shown by the dotted line in Fig. 27 (*b*). This method involves more machine work than the first.

25. Forging a Strap With Dies.—There is still another method of making the strap. After drawing the sides as in the first case, bend it in dies *a*, *b*, as shown in Fig. 28 (*a*) and Fig. 28 (*b*), *c*, *d*, representing the dies of a steam hammer. By this last method, time is saved in the bending; but the corners are very liable to be so drawn as to strain the stock and to weaken them.

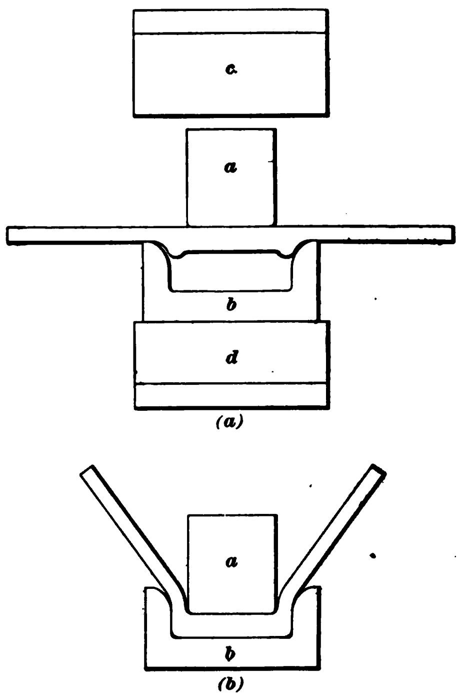


FIG. 28.

FORGING A ROCKER-ARM.

26. Forging Rocker-Arm From One Piece. — Take round stock that is great enough in diameter to give, when flattened, the dimension at *a*, Fig. 29 (*a*), and draw it to the form shown in Fig. 29 (*b*). This will require great care, for there is danger that the dimension *c* may be made too great, or, if this is right, that the dimension *b* may be too small. Flatten enough of one end to form the arm and draw to the form shown in Fig. 29 (*c*). Make the dimension *d*, Fig. 29 (*c*), to correspond to *d*, Fig. 29 (*a*). In flattening this piece, the work is done with the hammer, the side toward which the stock is drawn being made as true

and flat as possible from the shoulder to the end, and forming the recess at *d* by the use of the fuller. This leaves the projection at *f*, on the end, from which to form the boss. Next clamp the piece firmly near one shoulder and bend the flattened portion down, making the whole piece of the form shown in Fig. 29 (*d*). This may be done by clamping the piece between the hammer dies and driving the arm

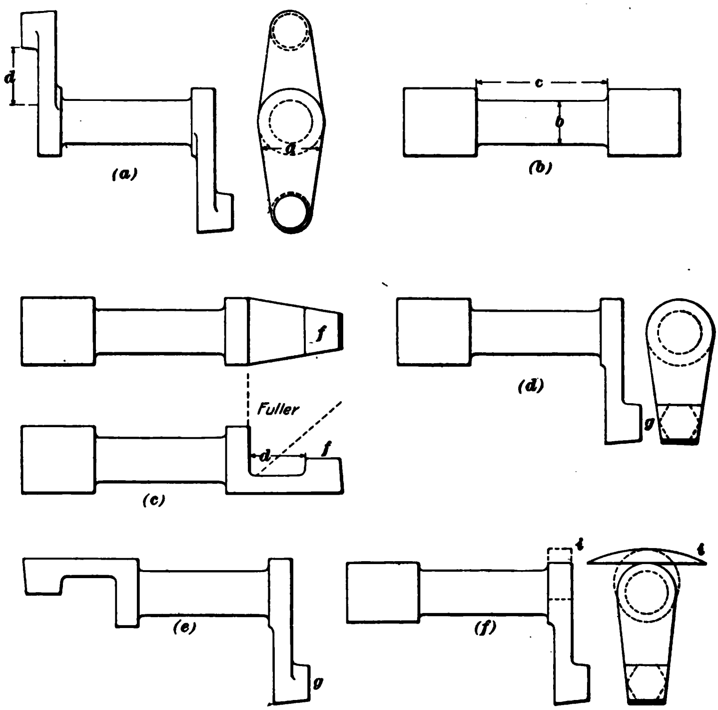


FIG. 29.

down with sledge hammers. Round the boss as shown at at *g*, Fig. 29 (*e*), first shaping to the form shown by the dotted lines at *g*, Fig. 29 (*d*), and then rounding to form the boss. The portion outside the shoulder on the other end of the piece is treated in the same manner, or both ends may be flattened and notched first, and then bent. Rocker-shafts are also forged by welding both arms to the shaft.

27. Forging Rocker-Arm With Welded Shoulders.—When it is not considered desirable to use stock that is large enough to form a shoulder of the required size, then the shoulder may be made in the manner indicated in Fig. 29 (*f*). The rocker-arm is made from the stock at hand, leaving it too small at the shoulders and the arms near the shoulders. A separate piece of stock is then drawn to the form shown at *i* in Fig. 29 (*f*). This is then bent to fit closely around the shoulder that has been formed, as shown by the dotted lines. A welding heat is then taken in one shoulder, and that side is welded; this is repeated on the other side. The subject of welding will now be taken up in detail. After both shoulders have been treated in this way, the whole piece is gone over carefully and dressed to shape.

WELDING.

GENERAL CONSIDERATION OF WELDING.

28. Definition.—If two pieces of iron are raised to a welding heat (which for iron is a white heat, at which it begins to flow) and their surfaces are brought in contact and pressed or hammered together, they will unite so as practically to form one piece ; this is called **welding.**

29. Use of Welding.—Each of the pieces treated thus far was made of a single piece of iron. Very frequently, however, it would be inconvenient or impracticable to make the forging out of one piece. If so, several pieces are welded together and the forging *built up*. Often it is necessary to join the two ends of a piece of iron, as in making a ring, or to join two edges of a sheet, as in making pipe; in such cases welding is generally resorted to.

30. Oxidation of Iron.—If a piece of iron is heated in contact with air, it will absorb oxygen from the air, thus forming a scale of oxide of iron on the surface. The hotter the iron, the more rapidly this scale will form. This scale

of oxide does not adhere to the iron very firmly and cannot be welded. It is therefore very important to guard against oxidation of the surface of the iron if a weld is to be made, because the scale of oxide will lie between the two surfaces of the iron and prevent them from coming in contact; and under these conditions it will not squeeze out if the pieces are pressed and hammered together. Two methods are employed to guard against the oxidation; both are based upon some means of protecting the hot iron from contact with the oxygen of the air.

31. Reducing Fire.—If the fire is a reducing fire, that is, if all oxygen is consumed in the combustion, then the gases coming in contact with the iron do not contain any oxygen that can unite with the iron. In this case there is nothing to oxidize, and the iron and its surface will remain clean. This is accomplished in the closed fire by having a thick bed of fire for the air to pass through before coming in contact with the iron and by maintaining a moderate blast. If, however, the blast passes through a thin bed of fire or if more air is blown through than the fire needs, the unused oxygen will oxidize the iron. Therefore, a thick bed of fire should always be maintained and the blast regulated so as to supply just enough air and not too much.

32. Protective Coating.—The other method is to coat the surface of the iron with some substance that will exclude the air. The substance used for this coating must possess certain qualities in order to answer the purpose. It must, of course, contain no oxygen that would unite with the iron. It must become fluid at a heat below the welding heat of iron and still not become too fluid at the welding heat; for if it became too fluid, it would run off and leave the iron exposed as before.

33. Fluxes for Iron.—Substances used for this purpose are called **fluxes.** Strictly speaking, most of them form a fusible mixture or slag, with the iron oxide, which offers the desired protection to the iron, but they use up some of the

iron to form the slag, therefore wasting iron. The slag is so liquid that it squeezes out from between the surfaces of the pieces being welded, thus leaving clean iron to be welded together. There are many fluxes; some of them will be described in connection with work for which they are best suited. The most common flux for iron is clean, sharp sand; this fuses readily on the surface of the iron and sticks to it during the heat, thus excluding the air. A very good flux for iron, but one that cannot be used on steel because it would draw the carbon out of it, can be made by mixing 2 ounces of calcined borax and 1 ounce of sal ammoniac. Iron is frequently welded without any flux.

34. Fluxes for Iron and Steel.—Sand and borax are very good fluxes for iron alone; but it is well to have a flux that can be used on both iron and steel. A very good flux for this purpose is made of potter's clay, wet with strong brine. This is dried and powdered and used like sand or borax. Another good flux that makes a *perfect slag* with the iron, is not too fluid, and does not injure steel, is made by mixing 3 ounces of pearlash or potash (potassium carbonate, K_2CO_3) with 1 ounce of dry clay. This is heated in an iron pot and when hot, 4 ounces of calcined borax is added. When cold, it is powdered and is ready for use.

CLASSIFICATION OF WELDS.

35. The different kinds of welds are designated according to the manner in which the contact between the pieces is made. There are many ways in which this may be done, and the selection of the kind of weld to use is made with reference to the use of the finished object, the strains it is to resist, and the equipment for making the weld. The following are some of the principal kinds of welds: *Scarf weld*, *butt weld*, *lap weld*, and *cleft weld*, all of which will be described in detail.

36. Scarf Weld.—In the scarf weld, the two pieces are *scarfed*, that is, they are thinned down, as shown in the

pieces *a* and *b*, Fig. 30. If the iron is of a uniform thickness, it is first upset at the point where the weld is to be made in order to gain a little in thickness; after this it is *scarfed.*

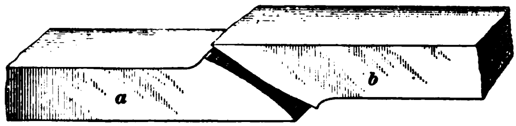


FIG. 30.

To do this, the upset end is thinned down, generally with the peen of the hammer, drawing it out thin at the point and crowding the metal together at the stock by drawing the hammer as shown at *a*, Fig. 31. The faces to be welded should be rounded as shown at *b*, Fig. 31, so that the pieces first come in contact at the center, in order to give the slag and impurities an opportunity to squeeze out as the weld is being closed.

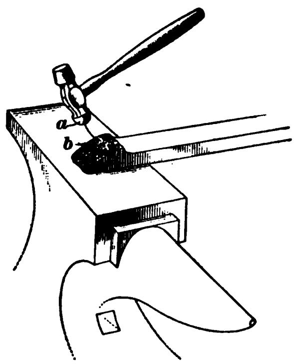


FIG. 31.

37. The scarfed ends of both pieces having been brought to a welding heat, the weld is made as follows: holding the shorter piece with the tongs in the right hand and the longer piece in the left (the scarfed face of both being down in the fire), draw both out of the fire and give them a sharp rap on the edge of the anvil to remove any coal or other substance that may adhere to the heated surfaces. Next bring the shorter piece to the position on the anvil shown at *a*, Fig. 32 (*a*), and follow with the longer piece, bringing it to the position

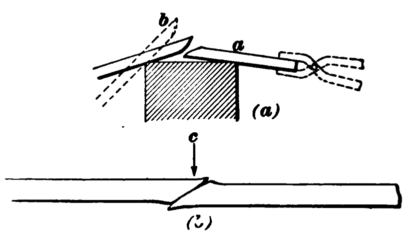


FIG. 32.

of the dotted outline *b*; without losing contact between the longer piece and the anvil, bring *b* down upon *a*, as shown in Fig. 32 (*b*). The contact of *b* with the anvil assists in controlling its movements. When *b* is placed on *a*, a slight pressure on it will hold both in relative positions while the tongs are dropped and the right hand relieved so that the hammer may be taken and a light blow delivered in the direction of the arrow *c*, Fig. 32 (*b*). As soon as the pieces are "stuck," the ends of the scarf may be brought down by delivering a few light blows on one side, and then the piece turned over and the other side fastened in the same manner before it has cooled from the welding heat. If the scarfs are made too long, it increases the surface to be welded and entails useless labor.

38. Butt Weld.—In the butt weld, shown in Fig. 33, the two pieces are generally upset a little first, and then welded together as shown. They are hammered on end to bring them together, and as this tends to upset the pieces some more, they are drawn out to the required size after the weld has been made. In preparing the ends, the surfaces to be welded are made convex as in the scarf weld, in order to allow the slag to work out.

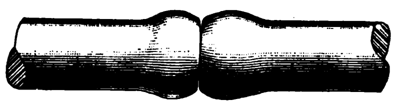


FIG. 33.

39. Lap Weld.—In the lap weld, the two pieces are laid together face to face, as shown in Fig. 34, and welded. As the faces are not rounded, the hammering is started at the center, gradually working toward the edges in order to work all the slag out. If the edges are welded up and any slag remains between the faces, it will keep the metal from uniting in the center.

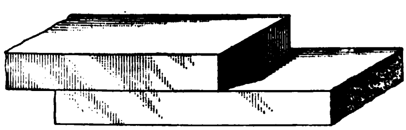


FIG. 34.

40. Cleft Weld.—When a weld is required to stand considerable strain, such as is caused by prying and bending,

the pieces are generally joined by the cleft weld shown in Fig. 35. One of the pieces *a* is upset to gain width and thickness, and is then split open on the end, as shown at *a*, and the two cheeks *c* and *d* spread apart; the other piece is then scarfed on both edges, as shown at *b*. In welding the pieces, they are hammered on end to get the weld to stick and then hammered on the edges to close the weld. The pieces should be so formed that the weld will catch first at the point *f* and the slag be forced out as the sides *c* and *d* are closed down.

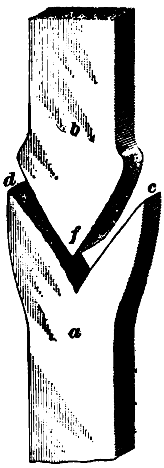


FIG. 35.

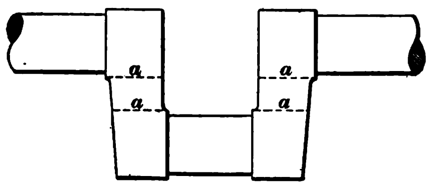


FIG. 36.

41. Building Up.—It is frequently inconvenient or impracticable to make a forging out of a single piece because of the shape it is to have. In such a case, the forging is

FIG. 37.

built up; that is, it is made out of a number of pieces that are forged to the approximate shape and then welded

together. Fig. 36 shows a built-up forging in which the welds are designated by the letters *a*, *a*.

42. Fagoting.—When a quantity of wrought iron in small pieces, such as scrap iron, turnings, etc., is welded up into a *slab* or *billet*, the operation is called *fagoting*. For this, a flat piece of iron, generally fagoted up of small pieces, is laid on a board and the pieces of scrap iron piled on top of this, making a firm rectangular pile with large pieces around the outside and small pieces in the center, or the flat piece on the board may be omitted, as shown in Fig. 37. It is then heated in a furnace and welded under a steam or a machine hammer.

EXAMPLES OF WELDING.

SCARF WELDING.

43. In order to illustrate some of the applications of the scarf weld, a few simple cases in addition to those already given, involving the various principles of welding in general and of scarf welding in particular, will be described.

44. Corner Plate.—If a corner plate, such as that shown in Fig. 38 (*a*), is to be made, two pieces of $\frac{3}{8}'' \times 1\frac{1}{4}''$ iron, each about 15 inches long, are heated at one end, keeping one of them near the edge of the fire so as to heat it slower than the other. When one is hot enough, it is taken from the fire and the end upset and then scarfed as shown in Fig. 38 (*b*). This is done by striking it and at the same time drawing the hammer toward the hand, as shown in Fig. 31, in order to draw the metal that way. The other piece is then taken from the fire, upset at the end, and one edge scarfed as shown in Fig. 38 (*c*). When both pieces are ready, they are put into the fire and raised to a bright-red heat, turning them occasionally to get the heat even. They

are dipped into the flux or the flux sprinkled over their surface, returned to the fire and raised to a good white heat on the *scarfs*. Some smiths use no flux in welding iron.

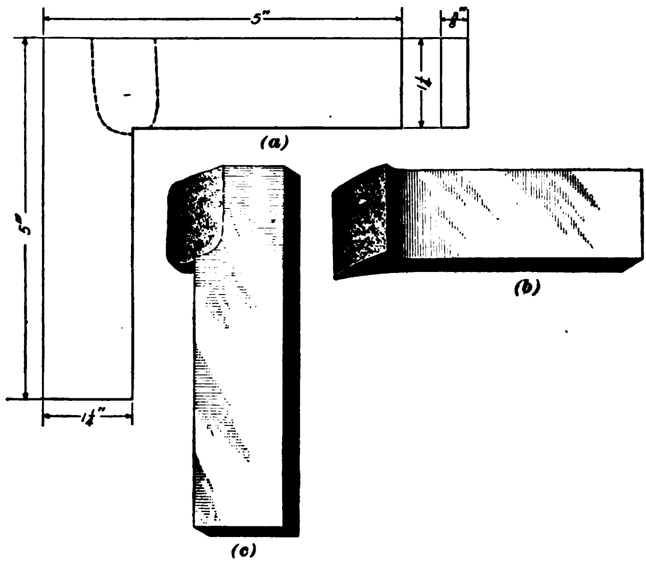
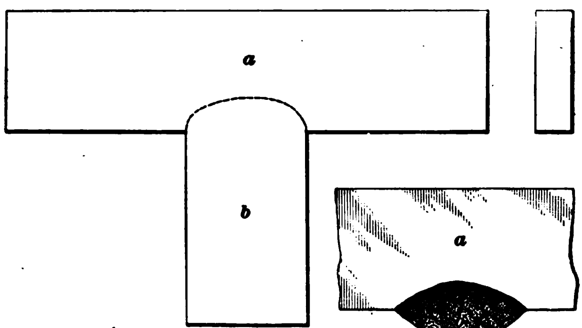


FIG. 38.

45. The pieces are turned occasionally to prevent the slag and flux from dropping off. As soon as both pieces begin to approach a welding heat, the blast is turned on harder in order to raise the final heat rapidly, and if it is thought necessary, a little more flux is thrown on the pieces while in the fire. When hot enough, the pieces are brought to the anvil and put together. In doing this, the pieces are held against the anvil, care being taken not to touch the cold anvil with the heated portion. When in line, the pieces are brought down flush on the anvil, having the piece in the right hand below the one in the left hand, so that the left-hand piece will be able to hold the other down while the right hand does the hammering. A few rapid blows will make the pieces stick; they are then turned over to bring the other face under the hammer.

The form of the scarf should always be such that the centers of the surfaces to be welded come in contact first; this will cause the slag to squeeze out as the pieces are hammered together. As soon as the pieces become black hot, they are reheated and the weld finished up. When black hot, the piece is struck against the horn on both sides to make sure that the weld is well made. A good weld will not open upon being bent and then straightened. If the weld is good, the corner is tried with a try square and finished perfectly sharp and square, on the edge of the anvil, as shown in Fig. 38 (*a*). The ends are then cut off, making each 5 inches on the long edge. When cold it will be seen that the weld is perfectly tight, the slag having all been squeezed out in hammering.

46. T Plate. — A **T** plate like the one shown in Fig. 39 (*a*) can be made in nearly the same way. The cross-piece *a* is upset in the center and the edge scarfed as



(*a*) (*b*)

FIG. 39.

shown at Fig. 39 (*b*), and the piece *b* is upset and scarfed on one end, as in the corner plate. When both pieces have been prepared, they are heated, fluxed, and welded as described in the construction of the corner plate.

47. Band Ring. — In making a band ring like the one shown in Fig. 40 (*a*), a piece of $\frac{3}{8}'' \times 1\frac{1}{4}''$ iron, 12 inches long, is upset at both ends. The ends are then

scarfed on opposite sides, as shown at *a* and *b*, Fig. 40 (*b*). The iron is then bent into the form of the desired ring. To do this, the iron is heated and then taken from the fire with the tongs, the end laid across the horn of the anvil, and hammered on the projecting end, moving it endwise until it is bent to the shape shown in Fig. 40 (*c*), the faces scarfed for welding being in position for welding, but about ¼ inch

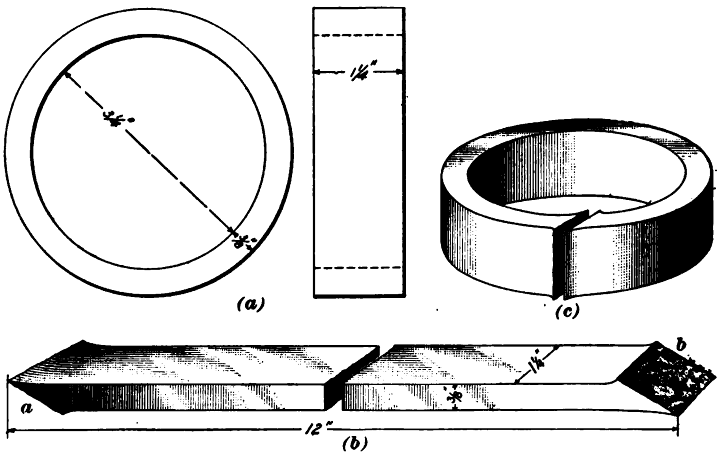


Fig. 40.

apart. The ends are next heated and fluxed and then raised to a welding heat. To weld the ring, it is brought to the anvil and slipped over the horn with the scarfed ends on the upper side of the horn. A few rapid blows with the hammer will make the weld, after which the ring is trued up so as to make it perfectly circular and to make the iron of the required width and thickness throughout. This is done over the horn of the anvil.

48. A very good way of bending the iron for a band ring or a similar piece is to bend a piece of ½-inch or ¾-inch round iron into a **U** shape, as shown in Fig. 41 (*a*). This is clamped in the vise with the open end up, and the iron to be bent is laid between the two projecting ends and bent by pressing the end sidewise, as shown in Fig. 41 (*b*). The

iron may be bent either hot or cold. If the iron is thin it is preferable to bend it cold, as hot bending is very liable to kink it. If thin iron is bent hot over the horn of the anvil, the jarring from the hammer blows is apt to make the projecting end sag down and lose its shape.

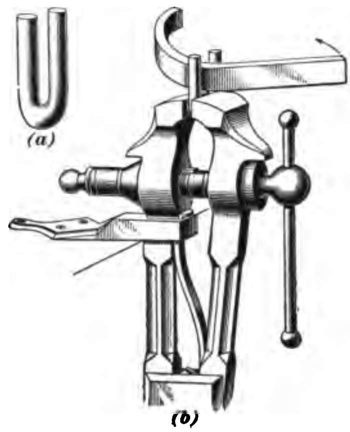


FIG. 41.

49. Ring Hook.—A ring hook of the form shown in Fig. 42 (*a*) may be scarf-welded and has, in its construction, a method of splitting stock for branch pieces that is valuable in smithing operations. The method will be illustrated by giving the details of construction of the piece shown.

50. Take a piece of Norway iron $\frac{3}{4}$ inch square and 5 inches long. Make a mark with a center punch 2 inches from one end, and draw it out round to 5 inches in length, leaving the stock of the form shown in Fig. 42 (*b*). Next, with a punch make the hole shown at *a* in Fig. 42 (*c*), split the stock out to the end, and bend the branches apart, as shown. Place the shank in a heading tool and bend the branches out, in the manner shown in Fig. 42 (*d*). During this part of the work, great care must be taken to prevent cracks from starting in the corners, as shown at *b* in Fig. 42 (*d*). When the iron has closed around cracks started in this way, they are known as *cold shuts*, or *gaulds*, and the piece is likely to be dangerously weak where they occur. They may be avoided by removing the piece from the heading tool when the branches have been partially bent out, placing it over the round corner of the anvil, and using the set hammer in the manner indicated in Fig. 42 (*e*). The branches are drawn out to the proper dimensions, scarfed, bent to the ring form, and welded as in the case of

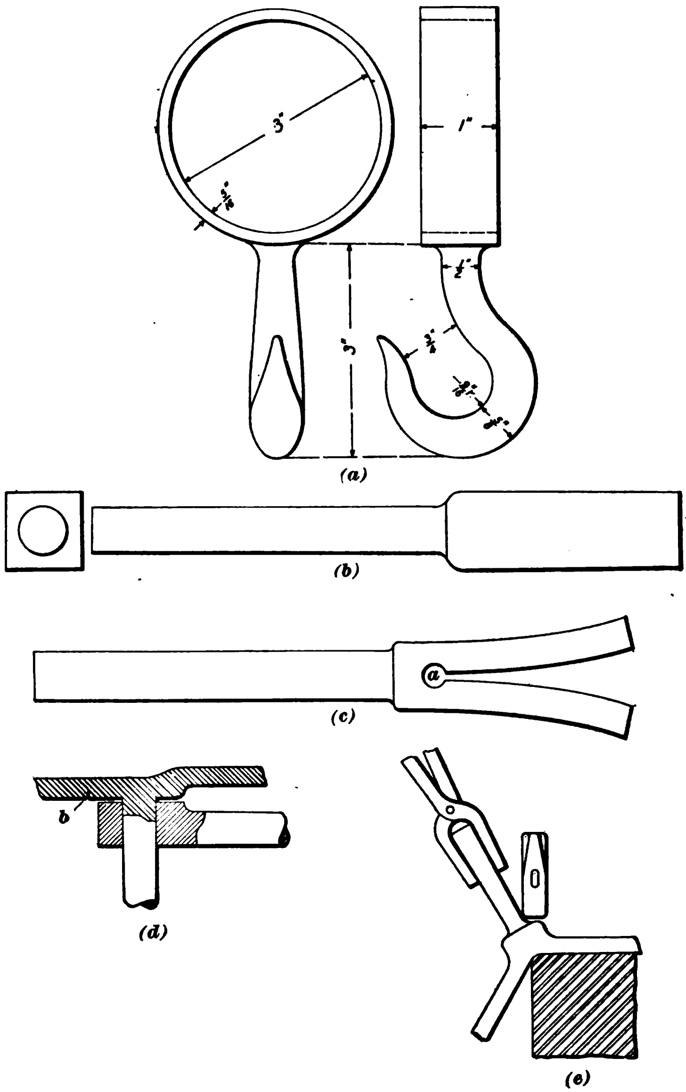


FIG. 42.

the band ring. The piece is held in the tongs by the ring while the hook is being shaped. No special directions are needed for this part of the work, as it is similar to examples already given. The finished piece should be sound, show no scarf or weld marks, and agree with the dimensions of the drawing.

51. Flat Ring. — In making a flat ring, as shown in Fig. 43 (*a*), a piece of $\frac{3}{8}'' \times 1\frac{1}{4}''$ flat iron, 14 inches long, is cut off and heated. Beginning at the end farthest from the tongs, the iron is bent edgewise over the horn of the anvil. As the circumference of the outside circle *a a a* of the ring is considerably greater than the circumference of the inner circle *b b b*, it is evident that the iron must be upset along the inner edge and stretched along the outer edge. This would make the iron thicker than $\frac{3}{8}$ inch at

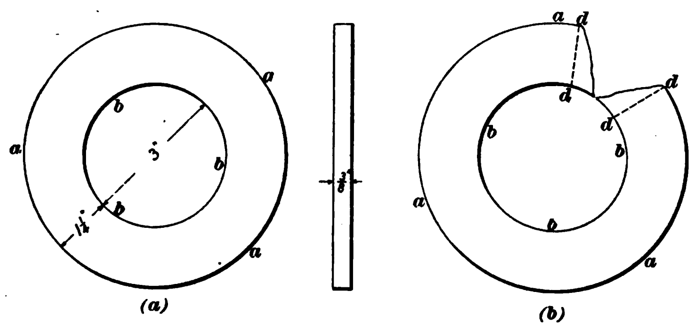


FIG. 43.

the inner edge and thinner along the outer. Besides this, the iron will buckle and twist in bending it. By hammering it flat on the anvil, using the flatter if desired, the iron can be kept flat and brought back to an even thickness. The width and thickness of the iron should be frequently tried with the calipers and should not be allowed to get far out of size. When bent, the iron must have the form shown in Fig. 43 (*b*); the corners must be cut off as shown by the dotted lines *d*, *d*. After this, the ends are scarfed and the iron bent on the anvil as shown in Fig. 44, until

the scarfs overlap, their inner surfaces remaining about $\frac{1}{4}$ inch apart, as shown in Fig. 45. The heat is then raised, the weld made, and the ring finished with the hammer. Many smiths scarf the ends of the ring before bending and form a little of the bend at each end when they form the scarf.

52. Forging a Chain. In making a chain like the one shown in Fig. 46 (*a*), six distances of $3\frac{1}{2}$ inches each are marked off on a rod of $\frac{1}{2}$-inch round iron, 29 inches long. These marks may be put on with soapstone or the rod may be nicked on the hardie. One end of the rod is then heated, scarfed, and bent

FIG. 44.

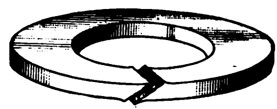


FIG. 45.

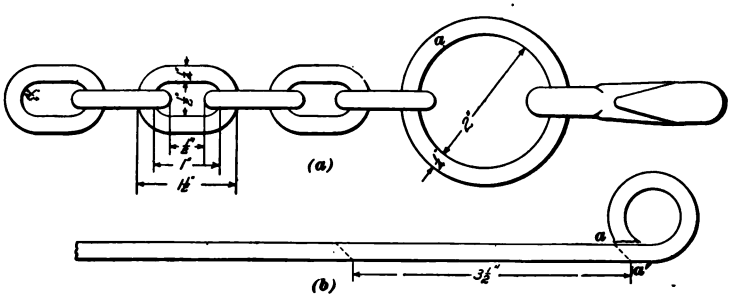


FIG. 46.

to shape, as shown in Fig. 46 (*b*). It is then cut off obliquely at the first mark, as shown by the line *a a'*; this makes only a single scarf necessary on each weld. The link is then heated, fluxed, and welded, and then bent into the proper

shape. By the time the first link is finished, the next section of the rod is hot enough to scarf and bend into shape. The rod being cut off at an angle makes it easy to scarf, but the hammer must be drawn, as was shown in Fig. 31, in order to crowd up the iron at the large end of the scarf. When the second link is ready to weld, it is fluxed and the heat raised. When at a welding heat, the link is brought to the anvil, the first link caught up in it, and the weld made, or the previous link may be caught up in it after fluxing and before putting it into the fire for the final heat. In this way the six links can be made, the heat for scarfing and bending a link being raised while the previous link is being welded.

53. Forging a Chain Ring.—When the six links of the chain have been made, the ring shown at *a*, Fig. 46 (*a*), can be made of the remaining 8 inches of the rod. The iron is scarfed at one end and bent into shape, when it is ready for welding; the first link of the chain and the chain hook, Fig. 23, are picked up in the ring, which is then welded. The chain can be finished by brushing it with a stiff brush and some sand and water, after which it is heated to a dull red and dipped into linseed oil or rubbed with a piece of oily waste, guarding carefully against fire in case the oil ignites.

54. Determining the Length of Material Required for Forging a Ring.—The following rule will be found handy for determining the amount of stock required for either band or round rings :

Rule.—*Add together the inside diameter of the ring and the thickness of the stock and multiply this by $3\frac{1}{7}$.*

EXAMPLE.—Required to determine the length of stock necessary for a ring of 2-inch iron having an inside diameter of 12 inches.

SOLUTION.— $12 + 2 = 14$; $14 \times 3\frac{1}{7} = 44$ inches. Ans.

BLACKSMITHING AND FORGING.

(PART 3.)

EXAMPLES OF WELDING AND FORGING.

SCARF WELDING.

MAKING TONGS.

1. Forging.—In making a pair of blacksmith's tongs, for holding flat iron, such as is shown in Fig. 1, a bar of $\frac{3}{4}$-inch square iron, not more than 2 feet long, is marked at 2 inches from the end and heated. When hot the marked

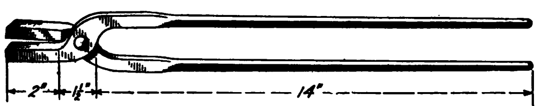


FIG. 1.

end is flattened down to a thickness of $\frac{7}{16}$ inch, leaving the shoulder, as shown at *a*, Fig. 2 (*a*), on one side. This may be done by holding it with the line on the edge of the anvil and flattening it down from above, as shown. The piece having again been heated is placed upon the anvil, as shown

in Fig. 2 (*b*), and flattened down for about 3 inches in length. The piece is then cut from the bar and the other end *g* drawn down to ½ inch round, as is shown in Fig. 2 (*c*), making the offset on the side opposite *a*. The end *d*, Fig. 2 (*c*), may be left a little larger and then scarfed for welding. Another piece is made like the first and a ½-inch round rod 12 inches long is welded to each to form the handles. A ¼-inch hole is punched through one of the pieces, as shown at *b*, Fig. 2 (*d*). The two parts of the tongs are held together and the hole marked in the second piece by punching it through the hole already made. The first piece is then laid aside and the hole punched through the other one.

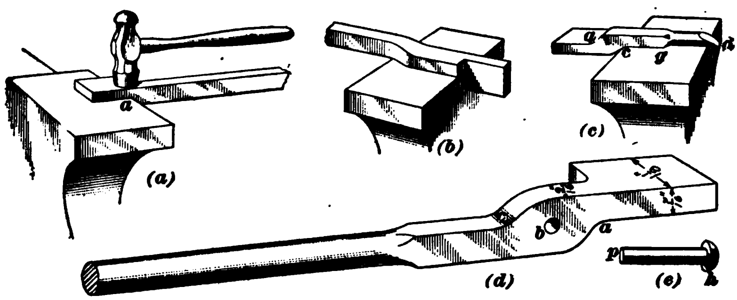


FIG. 2.

The pin or rivet that is to hold the two parts together is made by upsetting a ¼-inch rod at one end and forming it into a head. The pin, shown in Fig. 2 (*e*), is then cut from the bar, making it the proper length, and tried in the tongs to make sure that it fits. The pin is then put into the fire and heated on the end *p*. When hot, the finished head *h* is cooled by dipping it into water, but the end *p* is left hot. It is then put back into the fire and heated on the end. When hot it is put through the two holes and the tongs finished by riveting the end of the pin. It frequently happens that the rivet bends in the holes; this makes the tongs tight, but the jaws will not stay parallel. In such a case, the rivet is driven out while it is still hot and another one made. In some cases the handles or reins are not welded on, but are drawn down from the ¾-inch iron.

2. Inspecting.—In making tongs it is well to inspect the parts very closely before putting them together. A good way to detect flaws and defects is to heat the suspected part to a dull-red heat. This will show all defects, such as cracks, seams, poor welds, etc. The welds, angles, offsets in the jaws, and the metal near the punched holes are very liable to show defects. If the defects cannot be remedied, a new part must be made.

3. Taking a Heat Over Work.—Sometimes it is well to *take a heat over* the work. This consists of going over the piece, when it is at a white heat, with a light hand hammer. In this way the fibers that have become separated are rewelded and the forging improved.

4. Using the Fuller.—When making tongs, the fuller may be used to good advantage for working the material to approximately the correct form. A chisel should never be used for forming the shoulders, as it is almost sure to start a crack.

BUTT WELDING.

KNUCKLE-JOINT STRAP.

5. Forging.—To make a knuckle-joint strap, such as is shown in Fig. 3 (*a*), take a short bar of stock slightly wider than one-half the width *a* of the strap, and of the thickness shown at *b*. Make the notch shown at *c*, Fig. 3 (*b*), with the fuller, and then draw the end of the bar to the form shown by the dotted lines. Next, cut off this end of the bar at such a place as will give the piece shown in Fig. 3 (*c*), and hollow the face as shown at *d*. Make a second piece of the same form, except that the face *d* is convex instead of concave. There will now be two pieces, as shown in Fig. 3 (*d*). These pieces are to be welded together, the excess of width having been given that they

might close slightly at *f*, Fig. 3 (*d*), during the operation of welding.

To weld them together, heat the two pieces simultaneously in separate fires, or in a suitable furnace. When at a welding heat, place the pieces on the anvil in the relative position shown in Fig. 3 (*d*), and make the weld with light blows of sledge hammers, or place them between the dies of a power hammer and weld with light blows, being careful that the blows do not draw the opening too close. Too heavy blows are liable, also, to spread the edges of the weld and weaken it. The piece should be turned on its side, after the faces

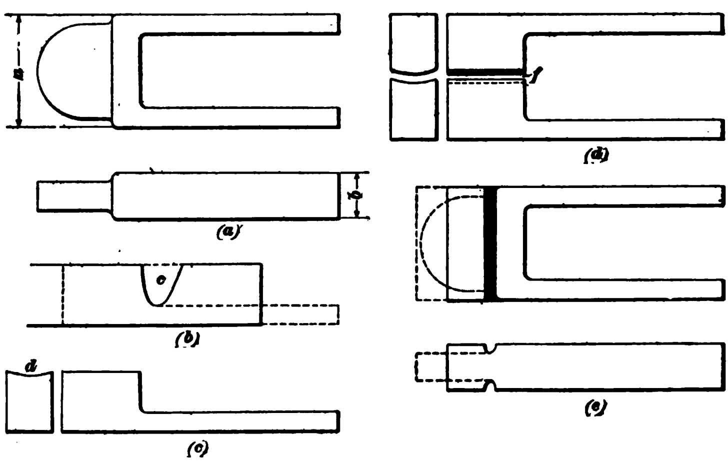


FIG. 3.

are welded, and the sides closed before the welding heat is lost. It must be remembered that the weld is due to the fluid condition of the metal at the surfaces being joined, and that the blows delivered should have only force enough to bring the surfaces closely together. After the weld is made, make the grooves shown in Fig. 3 (*e*) with the fuller, and draw the end out as shown by the dotted lines. Cut the end to the curved form shown in Fig. 3 (*a*) by the use of a hot chisel, and finish this end on the anvil in the usual manner.

ELECTRIC WELDING.

6. Electric welding has during the past few years taken a very prominent place in the mechanic arts; although it has, up to the present time, seldom been carried on in the blacksmith shop, it nevertheless comes under the head of blacksmithing.

7. Electric-Welding Machine.—The pieces to be welded are held in powerful bronze clamps; each clamp is connected with one of the terminals of a dynamo. The clamps are adjusted so that the pieces touch at the point where the weld is to be made. The clamp holding one of the pieces can be moved by means of a screw, or by hydraulic pressure, so as to either bring the pieces into closer contact or separate them, as may be desired. When the pieces are in contact, the current is turned on. The adjustable clamp is then drawn back a trifle, making it necessary for the current to jump across the space between the two pieces, thus forming an electric arc. This heats the ends to a welding heat in a very short time, and by forcing the clamp forward again, the two pieces are welded by pressing or hammering them together. The current is then turned off, and when sufficiently cold, the piece is taken out of the machine.

TOOL STEEL.

8. Distinction.—The work thus far considered has been exclusively in iron, some of the characteristics of which have been discussed and described. The work in steel presents some new problems because of the character of the material. The marked feature of steel is its ability to acquire various degrees of hardness. The degree of hardness attainable depends on the presence of certain foreign substances, chief among which is carbon. Besides carbon, other substances possess the quality of rendering steel hard; among these are tungsten, chromium, and nickel.

ANNEALING, HARDENING, AND TEMPERING.

DEFINITIONS.

9. Annealing.—By heating steel to a cherry red and then allowing it to cool very slowly by burying it in hot sand, ashes, or other substance that will hold the heat a long time, it will become soft and of a uniform structure throughout. This operation is called **annealing.**

10. Hardening. — If steel is heated to a medium cherry red and then chilled suddenly, it becomes hard. The degree of hardness reached depends on the suddenness with which it is chilled. The chilling may be done by exposing the steel to a cold blast, or the steel may be dipped into some cold liquid. This operation is termed **hardening.**

11. Tempering. — If a hardened piece of steel is slowly heated, it will gradually become softer as the temperature is raised. In this way it can be partially annealed to any desired degree of softness. When the desired degree is reached, the temperature must not be allowed to rise any higher, otherwise the annealing will continue as long as the temperature increases. Any further rise in temperature can be prevented by dipping the steel into some cold liquid. This operation of partially annealing the steel is called **tempering.**

SPECIMEN PIECE.

12. Preparing Specimen Piece.—This characteristic of steel that permits various degrees of hardness to be obtained can be illustrated by making a **specimen piece,** as shown in Fig. 4, and tempering it so as to present all the degrees of hardness from an annealed soft steel to one that is so hard and brittle that a sharp corner will scratch glass.

A piece of tool steel is drawn out wedge shaped, as shown in Fig. 4, measuring $\frac{1}{4}$ inch by $\frac{1}{2}$ inch at the small end, and

½ by 1 inch at the large end. The tapering part is made about 4 inches long, and 2 inches of stock ½ inch by 1 inch

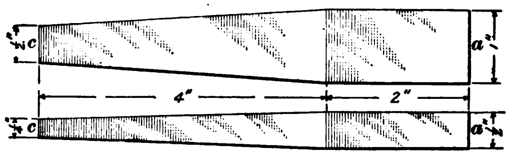


FIG. 4.

is left on the large end, making the total length of the piece 6 inches. This piece is filed bright and is then polished with emery cloth.

13. Hardening.—The piece is heated to a bright red and then dipped into cold water, holding it in the tongs by the large end. It should be dipped endwise and vigorously moved up and down until cold throughout. When cold it is again rubbed with emery cloth until bright. It will be found to have a mottled appearance; the file will not cut it; and it is hard and brittle.

14. Drawing the Temper.—If the end of a bar of iron at least 1 inch square is heated and the specimen piece laid on the hot bar so that the large end of the specimen piece rests on the bar, while a piece of cold iron about 1 inch thick is laid under the point to keep it from touching the hot iron, the large end *a* will rapidly become hot from its contact with the heated bar of iron, while the other end *c* will warm up very slowly. Soon it will be noticed that colors have begun to appear on the surface of the steel. The colors start near the heated end and gradually travel to the point, each making way for the next succeeding shade. The order in which the colors run from the hot toward the cold end is as follows: A very pale yellow starts at the hot stock and creeps toward the small end, being followed by a darker yellow, then by a brown, and so on, until by the time the yellow is close to the small end, the large end is of a deep slate color. This operation is called **drawing the temper.**

15. Temper Colors.—The colors in their regular order are generally known by the following names: Very pale yellow, pale yellow, full yellow (straw), brown, brown with purple spots, purple, light blue, full blue, dark blue, and gray.

NOTE.—The colors are caused by the oxidizing of the surface of the steel. The amount and character of oxidization, and, therefore, the color, vary with the temperature and indicate the temperature to which that part has been heated.

By the time the first tinge of yellow comes to within ¼ inch of the small end, the heat in the stock will be nearly spent; at this time the piece should be plunged into water and cooled for the purpose of fixing the temper and color. The piece will now be soft enough to file at the large end *a*, and some distance down, to about where the straw color shows, while the point is still hard and brittle. If the piece is cooled in the air by a blast, the colors will be brighter.

TEMPERING OF STEEL.

Color.	Temperature.	Specimen.
Very pale yellow......	430° F.	Lancets.
Pale yellow............	450° F.	Razors, surgical instruments.
Full yellow (straw).....	470° F.	Penknives, drills for iron.
Brown................	490° F.	Small cutlery, shears, cold chisels.
Brown with purple spots	510° F.	Axes, planes, pocket knives, wood chisels.
Purple................	530° F.	Table knives, large shears, drills for wood.
Light blue............	550° F.	Swords, springs.
Full blue..............	560° F.	Fine saws, daggers, swords, augers.
Dark blue.............	600° F.	Saws.

Temper Colors for Various Articles

Circular saws for wood, spiral springs.

Carriage springs, circular saws for metal.

Wood-boring tools, augers, planer cutters (to be filed), half-round bits.

Coopers' tools.

Hack saws (to be filed).

Carpenter's chisels, axes, stone-cutting tools, pen-knife blades, rock drills.

Dies for screw cutting, drifts, dental and surgical instruments.

Chasers, mowing machine knives, paper-cutting tools.

Milling cutters, reamers, twist drills.

Circular saws for bone and ivory.

Molding cutters.

Cold chisels.

Needles.

Shearing-machine cutters, plane irons.

Inserted saw teeth.

Taps.

Boring-bar cutters, dies for copper and leather, engravers' tools, lathe and planer tools, razors.

Scrapers.

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16. Temperatures.—The accompanying table shows what colors are produced at various temperatures; also, a few tools or instruments which are tempered to the various degrees of hardness obtained at these temperatures.

The temper should be drawn slowly, as it is easier to watch the change of color, and the danger of drawing it too far is reduced. Different makes of steel vary somewhat as to the degree of hardness corresponding to a given color, but the table may be taken as a fair average.

WORK IN STEEL.

COLD CHISEL.

17. Forging.—If it is required to make a cold chisel such as is shown in Fig. 5, a piece 6 inches long is cut from a bar of ¾-inch octagon steel. The piece is put into the fire so as to heat the end to a medium cherry-red color, for a distance of about 2 inches. The fire must be clean and the heat raised so as not to *soak* the steel in the fire, but at the same time getting the piece thoroughly heated without burning the corners. When a medium cherry-red color is

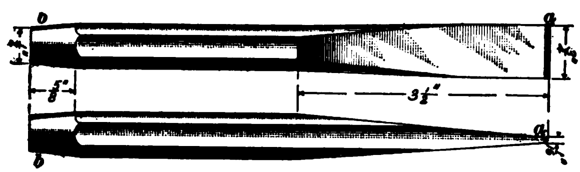

FIG. 5.

reached, the piece is taken out of the fire and the end drawn out to a wedge shape by rapid hammer blows. If the end begins to spread sidewise, it can be brought back into shape by a few hammer blows on the edges. The end is drawn out to an edge *a*, Fig. 5, by light hammer blows, taking care not to work it below a black heat, as this would tend to crack it. When the edge has been drawn out, the rough or ragged

part is cut off with the cutter, laying a piece of soft iron between it and the anvil so as not to cut against the hardened face of the anvil and thereby spoil the cutter. The head of the chisel is then rounded, as shown at *b*, Fig. 5. The chisel is now ready to be tempered, which operation may be divided into three separate steps: *annealing*, *hardening*, and *drawing the temper* or *tempering*.

18. Restoring the Uniformity.—The piece should be annealed in order to make it homogeneous. This is a step often neglected, but better results are obtained when it is done. When steel is worked, the structure changes; the thinner parts of the chisel have been worked more than those remaining thick, and have been heated more rapidly and to a higher temperature, and have also been cooled more quickly by the cold anvil and hammer. They are, therefore, more liable to be brittle; the steel is no longer homogeneous. It should be made so, however, before tempering, otherwise the various parts are liable to be tempered unevenly. The heat raised for hardening the tool does much to restore the homogeneity of the steel, but often this is not sufficient, and for this reason many prefer to anneal every tool before hardening it.

19. Annealing.—To anneal the steel, it is put into the fire and raised to a medium-red heat, taking care, however, not to overheat the thin edges. When uniformly heated, it is taken from the fire and laid in the warm ashes on the side of the forge and allowed to cool until the heat is no longer visible. It is then cooled by plunging it into cold water. This makes it homogeneous once more and it is ready to be hardened.

20. Hardening.—In order to harden the steel, it is heated to an even medium-red color (a little less than forging heat), and then plunged endwise into cold water. In plunging, care must be taken to plunge it straight, letting the edge strike the water first, and thrusting it down vertically and then moving it up and down. If plunged sidewise,

one side will cool sooner than the others and the piece will warp. This would not be so serious in a cold chisel, but in finer tools it would be a bad defect, and carelessness in coarse tools might lead to carelessness in finer ones. When the work has been plunged it should not be held quietly, but should be moved up and down, in order to bring its surface in contact with as much cold water as possible, thereby cooling it rapidly. The hot iron transforms the water with which it comes in contact into steam, which envelops the steel and keeps off the cold water; by moving the piece continually, the chilling becomes more effective. Moving the steel from side to side, however, has the same effect as plunging it sidewise.

21. Tempering.—When properly hardened, the faces of the chisel are rubbed bright with emery cloth or sandpaper, so that the colors can be watched while drawing the temper. If the head of the chisel is now heated, the temper will be drawn gradually, and when the brown color reaches the cutting edge, the point of the chisel is dipped into water to hold the temper where it is. The chisel can then be ground on a stone and tried on a piece of iron. The point should be the hardest part of the chisel, for if there is a harder part farther back, the chisel will be liable to break at that place.

22. Hardening and Tempering in One Heat.—In practice, a cold chisel is always hardened and tempered in one heat. The front end is heated to a medium red, letting the heat extend pretty far back. It is then taken from the fire and the point plunged into cold water, chilling it about 1¼ inches back. In plunging a piece of steel in this way, it must be moved up and down a little, so as to avoid starting a crack between the hardened part and the soft stock. As soon as the point has been sufficiently chilled, it is polished rapidly with emery cloth to make it bright. The heat still retained in the stock will gradually move along to the point and draw the temper, and the colors can be watched on the

bright part. When the desired shade is reached at the point, the chisel is dipped into cold water to hold the temper where it is.

23. Warps and Cracks From Hardening.—In dipping tools for hardening or tempering, great care must be taken to keep them in the water long enough to get the steel chilled throughout. If the tool is dipped, the outside becomes chilled and contracts, forming a hard, brittle shell for the heated and expanded interior. As the interior cools it also contracts, but being held to the already hardened shell it cannot contract to its original size; this causes an internal strain in the steel that may at times cause it to crack. For this reason the steel should not be plunged at more than a medium-red heat.

CAPE CHISEL.

24. If a cape chisel, of the form shown in Fig. 6, is to be made, the end of the bar of steel is drawn out to the

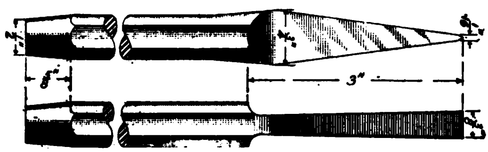

FIG. 6.

required shape, using the fuller for drawing down the sides of the blade. In forming the sides, place the stock on the round corner of the anvil, and bring it to shape in the manner shown in Fig. 7, taking care to have the shoulders of the same depth and opposite each other. Turning the piece frequently will assist in making the two sides alike.

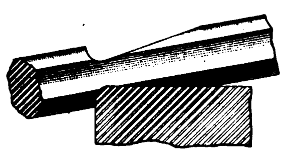

FIG. 7.

After the shoulders have been formed and the stock on the sides drawn down slightly with the fuller, the point is finished

as shown in Fig. 6. This finishing may be done with a hand hammer or with the flatter. When properly formed, the chisel is cut from the bar to the required length and the head formed, after which the chisel is annealed. If the edge is now filed, it will save grinding later on. The point is then hardened and the temper drawn in a single heat.

HAMMER.

25. For practice in working tool steel, the construction of the cross-peen hammer shown in Fig. 8 is useful. Two of the hammer heads may be made during the operation from the same piece of stock. Use a piece of tool steel $\frac{7}{8}$ inch square and $8\frac{1}{2}$ inches long. Lay off a center-punch

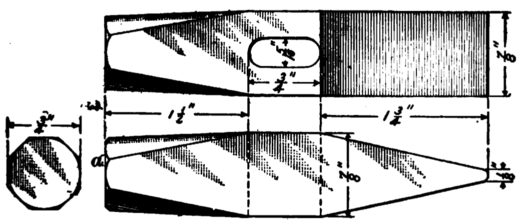

FIG. 8.

mark $1\frac{1}{4}$ inches from each end, and punch the holes for the handles at these marks, as shown in Fig. 9. To punch the hole, use an *eye punch* having an end considerably smaller than the required hole; drive the punch half way

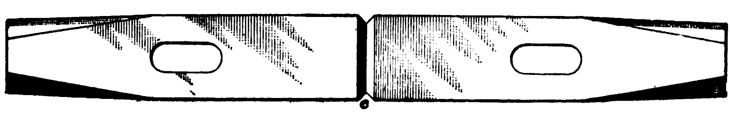

FIG. 9.

through from one side and then drive it to meet this hole from the other side; then finish the hole by using a drift that is the size of the required opening. To make the sides of the hole parallel and the opening of the proper shape, it

is necessary to work the drift through the hole made by the punch very carefully, keeping the steel closed around the drift during the operation. The stock must be hot enough to work freely.

Draw out the face end *a*, Fig. 8, to the form shown; the change in section from the square to the octagonal and the slight taper from the eye to the face will increase the length by $\frac{1}{4}$ inch or more. Holding in the tongs the end that has been drawn out, the other end is treated in the same manner. Next, the stock is cut apart at *c*, Fig. 9, and the peen ends are drawn to the form and dimensions shown in Fig. 8. Ball-peen hammers and those having other shapes may be made in nearly the same manner. The drawing may be done with a hand hammer or with the fuller and flatter.

DIAMOND-POINTED LATHE TOOL.

26. The stock for a **diamond-pointed lathe tool** for a small lathe should be of tool steel, 1 inch by $\frac{1}{2}$ inch in section, and the length $\frac{1}{2}$ inch less than that required in the finished tool; the form should be that shown in Fig. 10. Square one end and give it a $\frac{1}{16}$-inch bevel, as shown at *e*, Fig. 10, and then draw the other end to the form shown in Fig. 11 (*a*). Next draw to the form shown in Fig. 11 (*b*),

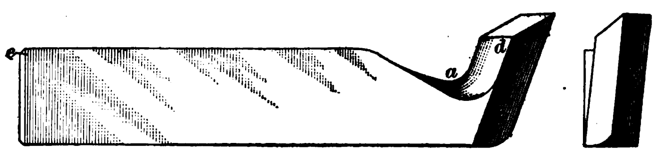

FIG. 10.

then place the inside edge *b* in contact with the face of the anvil, holding the body of the tool obliquely across the side, as shown in Fig. 12 (*a*), and deliver a few blows on the uppermost corner while it is in this position. Then shift its position until the other inside corner is in contact with the anvil face, as shown in Fig. 12 (*b*), and again deliver a few

blows on the uppermost corner. Return it to the first position, and deliver a few blows, then change it again, and so continue until the end is square in section and of the form shown in Fig. 10. Next, with a sharp chisel, cut off the point *f*, making it the required height, cutting from the face *d*, Fig. 10, and then bend the point to one side, as shown.

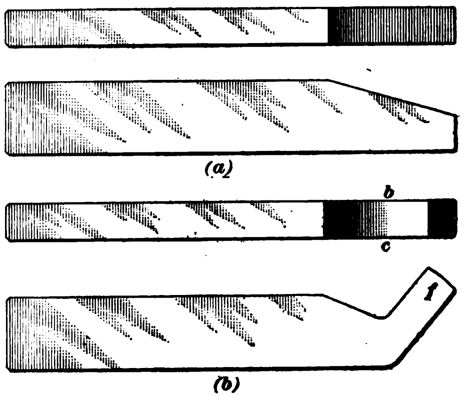

FIG. 11.

The tool is then hardened and the temper drawn to a light-straw color.

All the work must be done at a low heat or the tool will not do good work, and because of the low heat a crack is liable to form at *a*, Fig. 10, unless great care is taken. Larger tools of the same class may be made in the same manner.

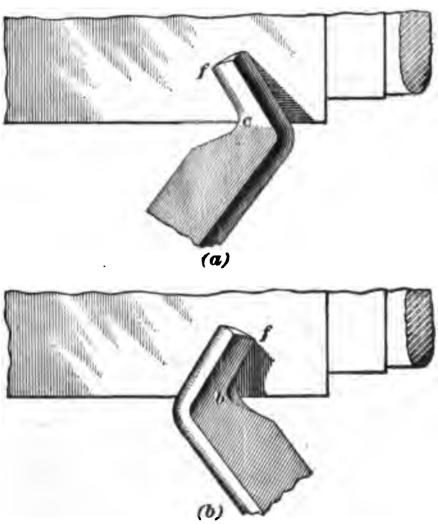

FIG. 12.

RIGHT-HAND SIDE TOOL.

27. To make a **right-hand side tool** assume that the stock is of tool steel 1 inch by ½ inch in section and of the length required for the tool, which is to

be of the form shown in Fig. 13. Bevel one end $1\frac{1}{4}$ inches back from the corner, as shown in Fig. 14 (*a*); then place it on the anvil in such a way that the corner *a* comes over the rounded edge, the piece being held as shown in Fig. 14 (*b*), and drive it down with blows delivered in the direction of the arrows

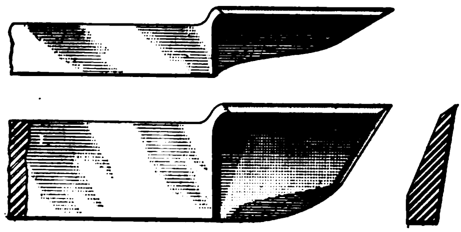

FIG. 13.

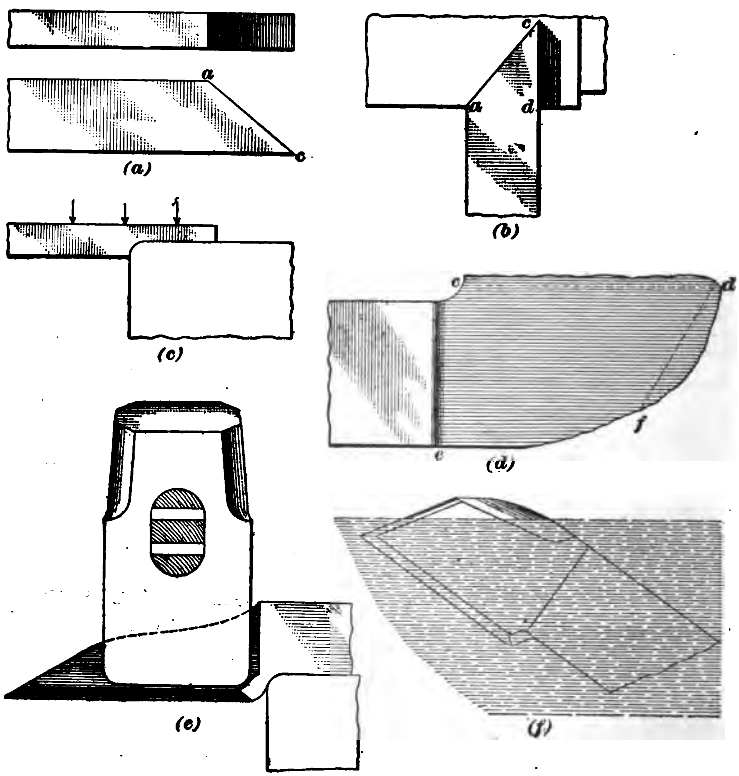

FIG. 14.

in Fig. 14 (*c*). This will bring it to the shape shown in Fig. 14 (*d*), the edge *c d* being made thinner than the back *e f*. When it is forged to the right thickness and the back properly shaped, the edge and point are cut off with a hot chisel to the shape indicated by the dotted lines in Fig. 14 (*d*).

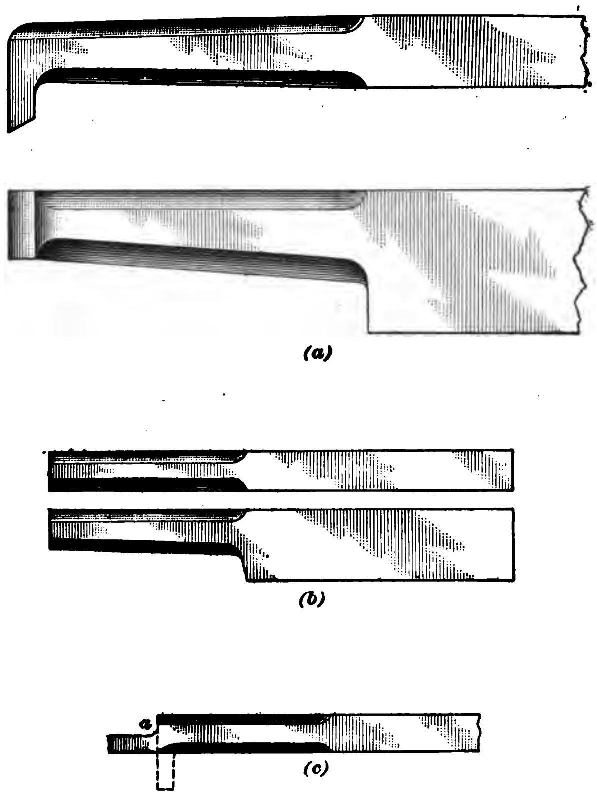

FIG. 15.

After the parts are made of the required thickness and dimensions, the edge is set over to one side in the manner shown in Fig. 14 (*e*), the piece being placed over the rounded corner of the anvil and the set hammer used in the manner indicated.

In tempering this tool, care must be taken that the thin edge is not overheated. The temper is drawn to a dark-straw color. It is well to dip this tool in the manner shown in Fig. 14 (*f*).

BORING TOOL.

28. The boring tool shown in Fig. 15 (*a*) is made in a manner nearly similar to the side tool. The same kind of stock is used, and a proper amount of the end is drawn down with the sledge and hammer to the form shown in Fig. 15 (*b*). Then $\frac{1}{4}$ inch of the end is placed on the anvil and the shoulder shown at *a*, Fig. 15 (*c*), is formed, and the end then bent to the shape shown by the dotted lines in Fig. 15 (*c*). The point is cut to the required shape with a sharp hot chisel and finished as shown in Fig. 15 (*a*). The tool is tempered to a dark-straw color, as was the side tool.

SPECIAL METHODS FOR HARDENING AND TEMPERING.

29. Importance of an Even Heat.—It is of great importance to have a tool heated evenly before hardening. Some parts of the tool may be exposed to the heat more than others, besides which the thin parts will heat rapidly while the thicker parts require considerably more time.

30. Heating in Molten Metal.—These difficulties are, to a great measure, overcome by heating the tool in molten metal, such as lead. The lead is heated until it melts, when the tool is put into it (generally suspended from a wire or with a pair of tongs clamped to it); the heat is then raised slowly. As the steel is not in contact with air, it may be allowed to soak a little. When the tool is of a medium cherry-red color, it is taken out of the lead bath and chilled.

31. Heating in a Sand Bath. — Small articles of steel are sometimes hardened by being put into a piece of

pipe or an iron box filled with sand, and, when heated, sand and all are emptied into the water trough. This hardens them all alike, and the temper may be drawn in oil or by heating a quantity of sand evenly and putting the articles into it to draw the temper. The heat of the sand is first ascertained by stirring it with a bright steel rod. The pieces may also be picked out of the sand bath with a pair of tongs and then plunged into the water. The tongs should be heated a little, however, to avoid chilling the steel where they touch it.

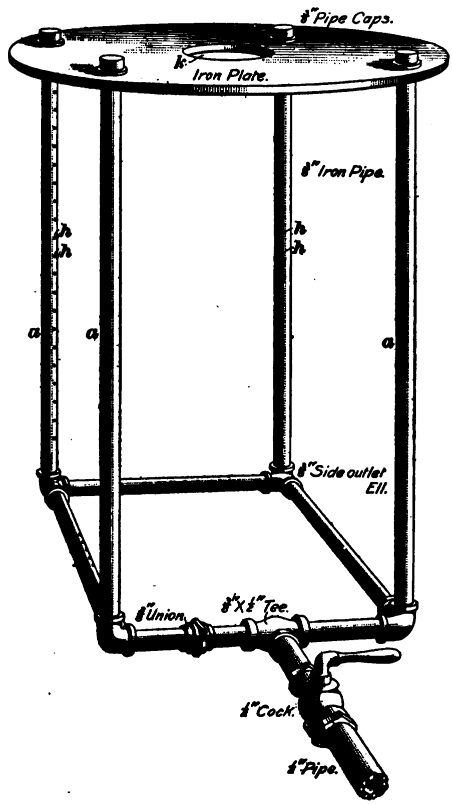

FIG. 16.

32. Spraying. If a piece of hot steel is dipped into water, the layer of water immediately surrounding it is raised to a great heat and small particles of hot steam envelop the steel, thus excluding the cold water from contact with it. This trouble is greatly overcome by shaking the piece violently under water. Moving the piece sidewise is liable to warp it in the same way as plunging it sidewise. This danger is averted by spraying the steel from all sides by means of some device like the one shown in Fig. 16, which consists of four vertical pipes *a*, *a*, set up at the four corners

of a square. The surfaces of the pipes facing the center of the square are perforated by a number of small holes *h*, *h*. The piece to be hardened or tempered is held through the hole *k* between the pipes and the water turned on. The piece is turned slowly so as to expose all sides to the spray. When the tool is thoroughly chilled, the water is turned off. The frame may be enclosed in a sheet-iron box or tank, and provision made for taking away the waste water.

33. Air Tempering.—It is said that the famous Damascus blades were annealed, then heated to a cherry red, and suspended by a string in the opening of a partly opened door. The tempering was always left for a cold, windy day in winter. The string in twisting brought all sides in contact with the cold draft, thus giving the proper degree of hardness without dipping into water or drawing. The dipping always has a tendency to impair the elasticity of the steel.

34. Hardening and Tempering in Oil.—If a tool is dipped into oil instead of water to harden it, the first chill received will be less than when dipped into water, but the oil fumes surrounding the steel have a higher temperature than has the steam from water; for this reason, oil hardening makes the tool less brittle than does water hardening. Springs and tools requiring elasticity are hardened in this manner.

35. Drawing Temper in Hot Oil.—In drawing the temper on a tool, it is very important that all parts of it should be tempered to the same degree of hardness. To do this, all parts must reach the same heat, and this is very difficult, if not impossible, in the open air. A draft, the cold tongs with which the article is held, and many other causes are liable to affect the temperature reached or the rapidity of the cooling, and thus make the temper uneven. If the piece is put into some liquid and heated to the required temperature in the liquid, the piece will be heated

evenly throughout and will also be protected from all external influences like drafts, etc. Linseed oil is generally used for this purpose.

36. Ascertaining Temperature of Oil.—For drawing the temper of steel in oil, a deep pan having a handle is filled half full of linseed oil and supported directly over the fire. As the oil becomes hot, a light white vapor begins to rise from it. A bright steel rod dipped into the oil will turn to a pale-straw color, showing that the oil has reached a temperature of 450° F. As the oil becomes hotter, the vapor becomes darker and heavier; if the end of the rod is put into it again, it will turn brown, 490° F. After a while the vapor will appear black; if the rod is then held into the oil for a few moments, it will turn purple, 530° F. If the heat is increased until the vapor can be ignited with a burning chip of wood but can be blown out quite easily, it is a sign that the oil has reached a temperature of 550° F., and will turn the rod light blue. This is the proper heat for springs of low-grade steel. If the heat is increased, the oil will boil over and the fumes ignite so that they cannot be blown out; this shows that the oil has a temperature of 600° F., which will turn the steel dark blue. This is the temperature of the high-grade steel springs.

37. Burning Off.—The fact that linseed oil ignites at 600° is taken advantage of in the process of *burning off* frequently used in tempering springs. The spring is hardened by immersing it in linseed oil. When cold it is taken out and the oil that still adheres to it is ignited and allowed to burn off. This produces a temperature of at least 600°, which will draw the temper of the spring. This coats the spring with a black surface that makes it rust-proof. If necessary, as in thick pieces, the burning off is repeated. Care must be taken to see that the burning off is not continued too long, for while the oil ignites at 600°, the temperature of the burning oil rises much above this, and hence there is danger of overheating the piece.

FLAT SPRING.

38. Forging.—To make a flat spring, such as is shown in Fig. 17, a piece of steel is drawn out flat and slightly tapered, care being taken to make the taper very regular, and finishing it with a flatter until it is perfectly straight. The steel is then annealed and filed and then ground on a stone to remove all irregularities and uneven spots. It may then be bent cold in the hand, or over the horn of the anvil without hammering; or it may be heated and then bent into the shape shown in Fig. 17. When evenly bent it is ready for hardening.

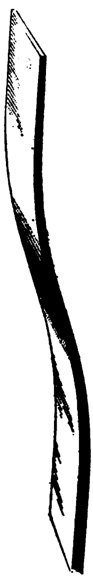
FIG. 17.

39. Hardening.—If the fire is large enough to give an even heat to the entire spring, it may be heated in the open fire and then plunged into water or oil, care being taken to avoid warping. Another way is to heat the steel in a pan of sand, which will make the heat more even.

The heating should be slow and even and the piece raised to a cherry-red heat; and when cooled in water, it may be held in the tongs and dipped vertically. After treatment in this manner, the surface should have a mottled appearance, being clouded with black and with white spots; if it has not this appearance, it is probably not hard enough and should be hardened again.

40. Tempering.—When hardened, the steel is rubbed bright with emery cloth and then tempered to a dark-blue shade. The tempering can be done over the open fire, or in a sand bath previously heated to the proper temperature, or over a piece of hot iron. When drawn to a dark-blue color, the spring is plunged into cold water.

The temper may be drawn by holding it over the fire and heating it slowly and evenly by moving it back and forth, using a light draft. To know when it has reached the right temperature, a pine stick, sharpened to a point, is rubbed over the surface, and when sparks follow the stick the right

temperature has been reached; the spring is then plunged into oil or water.

Another method of tempering a hardened spring is to dip it into oil and hold it over the fire until the oil begins to blaze; then dip it in the oil again and heat it as before, repeating this process three times. Care must be taken that the oil does not ignite before the temperature of the steel reaches approximately the ignition point of the oil and that the oil is not allowed to continue burning on the spring, as this would overheat the spring and draw its temper too far.

41. Testing.—The spring may be tested as follows: Its shape is first marked off on the bench or on a sheet of paper, then it is clamped in the vise at the thicker end and the projecting thin end bent forwards and allowed to spring back several times. It is then compared with the drawing to see whether it has changed its form. If so it is too soft;

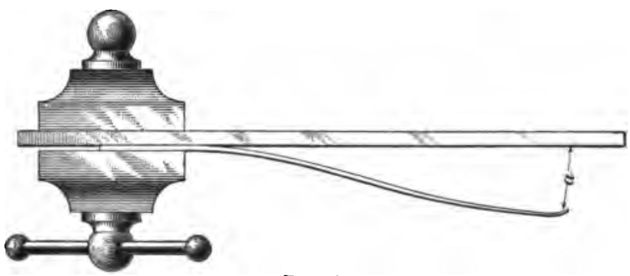

FIG. 18.

if it breaks it is too hard. Or it may be clamped in a vise with a piece of iron, as shown in Fig. 18, and the distance *a* measured; it is then forced down until the point touches the iron. After it is released, if the distance *a* measures the same as at first, it is properly tempered. Do not strike it or drop it after tempering, as either act may break it.

HARDENING PREPARATIONS.

42. Hardening Solutions.—Certain salts may be dissolved in the water used for chilling the steel that will effect a more rapid cooling, some on account of their cooling

properties, others on account of their tendency to retard the formation of steam on the hot surfaces.

The following solution will be found very serviceable for hardening as well as for cooling in drawing the temper: Dissolve in 2 gallons of rain water, 1½ ounces rock salt, 1 ounce saltpeter, 1 ounce sal ammoniac, 1 ounce corrosive sublimate. The steel is heated to a cherry red and dipped into the solution. When cold, the temper is drawn. This solution is very poisonous and should be handled with great care.

43. Hardening Paste. — Steel may be hardened by heating it to a cherry red and then coating it rapidly with a paste made of 4 ounces salt, 1 ounce wheat flour, 2 ounces water. After this the piece is put back into the fire until it is cherry red, and then plunged into cold water.

44. Chloride-of-Zinc Solution. — If steel is to be made very hard, it is heated to a cherry-red color and then plunged into a solution of chloride of zinc. A drill hardened in this way will drill glass.

45. Common-Salt Solution. — One of the simplest and at the same time one of the best hardening solutions consists of a saturated solution of common salt and rain water. This solution is employed quite extensively by tool smiths.

46. Mercury.—Cooling steel in mercury has the same effect because the mercury, being a good conductor of heat, carries the heat away from the immersed steel rapidly, thereby chilling it quickly. Care must be taken not to inhale the fumes, as they are poisonous. Wheels of glass-cutters are frequently hardened in this way.

SELF-HARDENING STEEL.

47. Comparison.—The steel from which sharp-edged tools, springs, and instruments are made must be tempered to give it the proper degree of hardness. There are grades

of steel, however, that are so hard that they will hold an edge even while perceptibly red. These are known as **self-hardening steel.** *Mushet steel* is probably the best-known kind. All self-hardening steels are, strictly speaking, alloys; two or more metals are mixed to give a product having the required properties. The metals alloyed with the steel are, of course, added in very small quantities, but the effect produced is marked. Tungsten and manganese are generally alloyed with the steel to make it self-hardening. Chromium is sometimes added to these, and it is then called **chrome steel.** Chrome steel is very good at first, but it frequently loses its good qualities after redressing several times.

48. Properties.—Self-hardening steel, even in the bar, is extremely hard and brittle. It cannot be cut cold. It must be worked at a cherry-red heat and not worked below a dull red. It will crumble if worked too hot or too cold, and requires hard and persistent hammering. If plunged into water while hot, it will fly to pieces. It is very extensively used for lathe and planer tools for roughing work. The work can be run at a greater speed, and a heavier cut taken, than with a tool of ordinary tool steel, because the heat from the friction will not draw the temper from the cutting edge.

49. Treatment.—When a tool has been made of self-hardening steel, it is laid aside in a cool place; when cold it is ready for use after it has been ground, which is generally done on an emery wheel. If it is not hard enough, the tool is heated to a cherry red and a blast of cold air turned on it until the tool is cool. It may be annealed soft enough to be worked in a lathe by heating it and then burying it in sawdust, sand, or ashes.

50. Restoring.—Self-hardening steel frequently crumbles while being dressed at a temperature that did not cause it to crumble before. This is a sign that it is no longer homogeneous. The tool can sometimes be *restored* by heating

it and cutting off the crumbled portion, then heating it uniformly throughout to nearly a lemon color, without soaking it in the fire, and allowing it to cool slowly in a warm, dry place. After this treatment, the steel may be worked as before. The same treatment is good for high-grade steel that has become refractory (no longer homogeneous) by continued working.

51. Aluminum Steel.—A small percentage of aluminum ($\frac{1}{2}$ ounce or 1 ounce to the ton) is sometimes added to steel in order to make it flow better in casting.

52. Nickel Steel.—Armor plates are sometimes made of steel alloyed with nickel (5 per cent. and upwards). This makes a very strong product that does not easily corrode.

WELDING IRON TO STEEL.

53. Characteristics of Each.— In welding iron to steel, the characteristics of each material must be taken into account. Iron welds at a white heat, but steel must not be raised above a bright-cherry heat. Sand flux is very good on iron, but steel requires something more fusible. In this case, borax may be used.

54. Borax for a Flux.—If a piece of flat iron is heated to a bright cherry red and some raw or crystallized borax sprinkled over it, the borax will boil and bubble so that very little of it actually comes in contact with the iron, and if the iron is put back into the fire most of the borax will be rubbed off. It is evident that borax in this condition is not fit to use as a flux. The boiling and bubbling is caused by the water contained in the borax. The heat changes the water into steam, which swells and honeycombs the mass. The water may be expelled by heating a small quantity of borax in an iron ladle, stirring it occasionally, and adding more borax as the mass melts. This operation is called *calcining*. The calcined borax is poured on a cold surface, and when sufficiently hard it is powdered. This powder is used for

fluxing steel. Calcined borax is also called **borax glass.**

55. Making the Weld.—To make a weld, the fire is cleaned so as to remove all cinders, ashes, etc., and then the iron put in and raised slowly to a welding heat. When this point is nearly reached, the steel is put into the fire and heated as rapidly as possible. When each is near its welding heat, it is dipped into its flux, the iron into the sand and the steel into the calcined borax, or both into borax. They are then put back into the fire and brought to their welding heats, the iron to a white heat and the steel to a bright cherry. They are then taken from the fire and welded rapidly, working them down to a dull-red heat. The weld is then reheated and gone over with a light hammer.

MAKING FLAT DRILLS.

56. Forging.—In making a long-shank, flat drill, such as is shown in Fig. 19, the point is made of steel, but the shank is made of iron. The steel is welded to the iron by a cleft weld before forging the drill point. The steel is formed as shown at *a*, Fig. 20, and the iron cleft is shown at *b*. The iron is heated to a red heat, the cold steel driven into the cleft, and the iron closed down about the steel. A welding heat is then taken on the joint, using borax as a flux; the iron being outside protects the steel from being burned. When heated to a bright cherry red, the pieces are taken from the fire and welded together. The shank is then cut to the proper length and the end forged square to fit into the brace or ratchet and the point forged to the proper form.

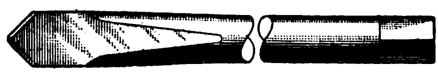

FIG. 19.

FIG. 20.

57. Tempering.—When forged, the drill is annealed, hardened, and the temper drawn to a full yellow. When ground it is ready for use. The temper of the drill may be drawn by the heat in the shank. If the shank is not hot enough, a large nut or a heavy piece of iron having a hole through it is heated and slipped over the shank close to the point, and the drill held so that it does not touch the hot iron. The heat that radiates from the iron will soon draw the temper. A pair of hot tongs is often used for drawing the temper, the work being held near the point and the temper allowed to run out as desired.

STEELING.

58. Pick Point.—**Steeling** is the operation of welding a steel edge or point on a tool, the stock of which is made of iron. The cleft weld is generally used for this purpose, on account of its strength. If the point *b* of a pick mattock, shown in Fig. 21, is to be steeled, the iron is split open, as shown at *f*, Fig. 22, and prepared for a cleft weld. The bar of steel *d* is then scarfed on both sides, as shown, both pieces heated, and then welded

FIG. 21.

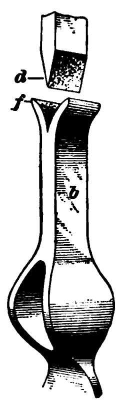

FIG. 22.

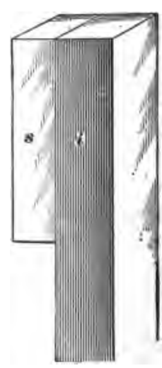

FIG. 23.

together. After this the point is drawn out to the required shape, as shown in Fig. 21. Picks, axes, adzes, and other similar tools are generally steeled in this way.

STEEL FACING.

59. When a sheet of steel is welded to an iron back, the operation is called **steel facing.** The steel is frequently welded on in a thick piece and the iron and steel drawn out thin after they have been welded. Plane irons that have a steel face and an iron back are generally made in this way. The iron *i* and steel *s* are welded together so as to make a square piece, as shown in Fig. 23, and this piece is then drawn down to the required thickness.

HARDENING AND TEMPERING FURNACES.

60. Advantages.—In hardening and tempering tools, such as machine knives, taps, milling cutters, long twist drills, reamers, etc., there is danger of warping the tools by uneven heating, or by a cold draft, or by some other external influence. The thin parts will heat more rapidly than the thicker ones and will also cool more quickly, thus sometimes causing the tool to crack in the sharp corners. This cracking can be averted to a great extent by heating the steel in a special **hardening furnace.**

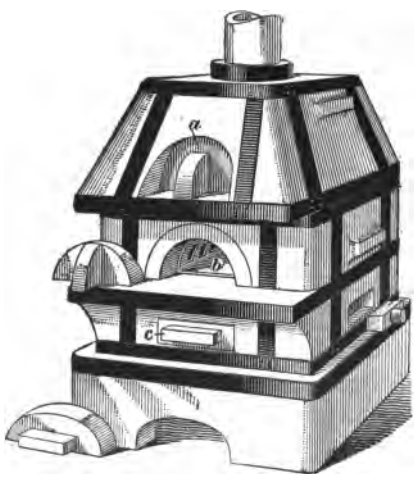

FIG. 24.

61. Muffle Furnace.—Fig. 24 shows a muffle furnace that is lined with firebrick throughout, coal, coke, or charcoal being used for fuel. If a blast is used, it is supplied through a blast pipe that opens into the ash-pit; a valve is used for controlling the blast. The steel to be heated is placed in the muffle *b*, which is surrounded by the fire. The grate is level with the bottom of the opening *c* and the fuel is put in through the door *a*. Gas or oil is sometimes used for fuel in muffle furnaces. If gas is used, it is mixed with air on its way to the burners.

62. Gas Furnace With Chain Conveyer.—Fig. 25 shows a gas furnace in which large quantities of small articles, all of which have the same shape, can be tempered continuously. The pieces are dropped into the links of a

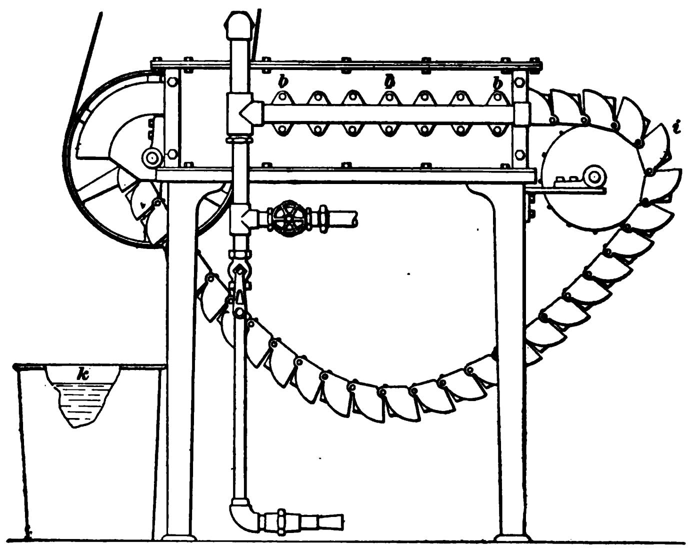

FIG. 25.

chain conveyer at *i* that exposes them to the heat while they are traveling through the furnace, and then drops them into the cooling bath *k*, placed at the other end of the machine. The furnace is heated by gas, which is mixed with air and then distributed to the burners *b*, *b*; when

once set and the speed of the conveyer adjusted, the furnace will heat all pieces to the same temperature. The furnace is used for heating steel, for hardening, and also for drawing the temper. When used for hardening, the conveyer is made to travel slowly and the heat is made more intense; whereas, if the furnace is to be used for drawing the temper, the chain travels through the furnace rapidly and the temperature is kept at the heat required to draw the temper to the desired degree of hardness.

63. Sand Drawing Furnace.—In the furnace shown in Fig. 26, the pieces to be tempered are fed into the furnace at one end *a* and conveyed to the other end *b* by means of a spiral conveyer. While passing through the furnace, the

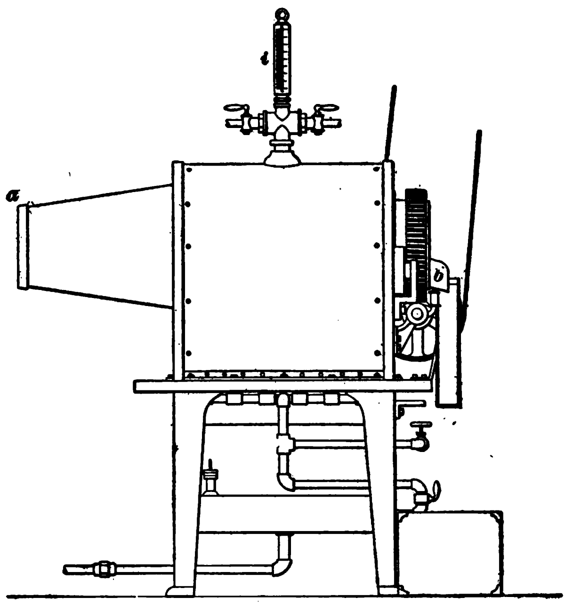

FIG. 26.

pieces are brought in contact with hot sand, which draws their temper. The sand is heated by gas burners and the temperature is determined by means of a special thermometer *i*, called a **pyrometer.** The pieces are not chilled, but

allowed to cool in the air. This is frequently done when a bright color is wanted for the sake of appearance, as in blued screws, etc.

64. Lead Furnace.—Fig. 27 shows a lead-heating furnace used for heating steel for hardening. The lead in the pot *d* is heated and kept in a molten condition by gas flames. The steel is put into the lead and held in it until it has acquired the proper temperature throughout. It is then taken out of the molten metal and thoroughly chilled by plunging or spraying. The burners are inside of the outer casing *c*; the lighting being done through the holes closed by the stoppers *f*, *f*.

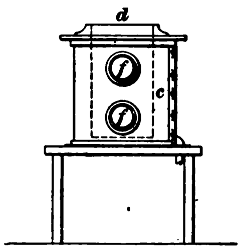

FIG. 27.

65. Oil Drawing-Furnace.—Fig. 28 shows an oil bath used for drawing the temper. The oil in the tank *s* is

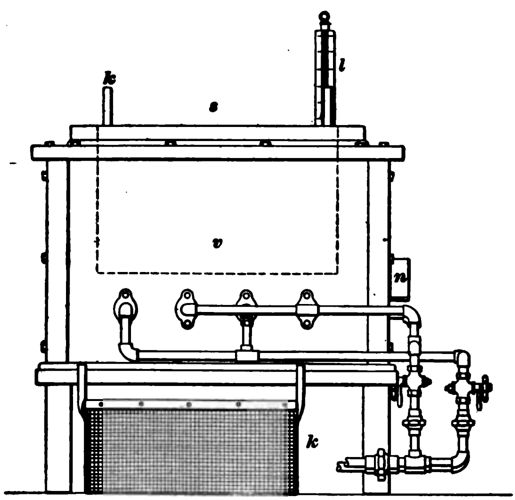

FIG. 28.

heated to the required temperature by gas flames between the tank *s* and the outer casing *v*. The lighting hole is shown closed by the plug *n*. The articles to be tempered

are put into the basket *k* and then immersed in the hot oil. When the temper has been sufficiently drawn, the basket is lifted out and the pieces allowed to cool off. The temperature of the oil is ascertained by means of the thermometer *l* and is kept the same by regulating the gas and air supply.

66. Oil Hardening and Tempering in One Operation.—Articles are sometimes hardened and tempered in one operation, as follows: The pieces of steel are heated to a cherry red and then plunged into oil that has been previously heated to the temperature required to produce the desired degree of hardness. Owing to the fact that the temperature of the oil is raised by throwing the hot pieces of steel into it, the thermometer must be closely watched and the gas flames regulated accordingly. If the oil bath is large, the effect will not be so marked as with a small quantity of oil. Linseed oil is generally used for this purpose.

CASE-HARDENING.

67. Theory of Case-Hardening.—The distinguishing feature of steel is its hardening quality. Wrought iron does not possess this characteristic, but it can be subjected to a treatment called **case-hardening** that will, as the name implies, harden it on the outside. The operation of case-hardening consists of two steps, namely: first, causing the iron to absorb carbon by heating it to a red heat in the presence of carbon and thus transforming the outside of it into steel, and, second, chilling it suddenly to harden the steel thus formed.

68. Cyanide Method.—The simplest method of case-hardening is to bring the iron to a bright-red heat and then rub it with a lump of cyanide of potash or ferrocyanide of potash. It is then again rapidly heated and plunged into cold water. If the second heat is too slow and the iron is allowed to soak, the carbon that it took up from the cyanide will diffuse throughout the iron and be lost to the surface where it is required. The fumes from the cyanide are as

poisonous as the cyanide itself and must not be breathed. It is best to hold the cyanide in a pair of pick-up tongs while case-hardening. This keeps it farther away from the nostrils and also avoids getting the hands covered with it.

69. Carbonizing.—Small pieces, such as parts of guns, sewing machines, and bicycles, are often made of wrought iron and case-hardened by a method very much like the process used in the manufacture of blister steel. The carbonizing is not carried far enough to allow the carbon to penetrate clear through, but the surface is transformed into steel.

The pieces are packed in charcoal, or other material containing carbon, in air-tight boxes made of iron and then heated to a cherry red for 24 hours. They are then, while hot, thrown into cold water. Charred bone, leather, or hoofs are often used in place of or with charcoal with very good results. Some persons claim that if cast-iron borings are mixed in, they serve to conduct the heat to the pieces more evenly and, therefore, give better results. If some salts are dissolved in the water used for chilling, the effect will be the same as in hardening steel.

70. Carbonizing in Clay.—Articles may be case-hardened by coating them with a thick paste made of charcoal and strong brine, and then embedding them in a lump of clay that is baked for 2 or 3 days and then thrown into cold water. The clay cracks up into small pieces and the iron is picked out when cold.

ANNEALING.

ANNEALING STEEL.

71. When steel has been unevenly worked under the hammer and has, in consequence of this, lost its uniformity of structure, it may be restored to its normal condition by submitting it to a cherry-red heat and then allowing it to cool to a black heat on the side of the forge. If, however,

the steel is to be cut with tools, as in a lathe or planer, or if it is to be filed or cut with taps or dies, a more efficient process of annealing must be used to make it soft enough to be easily cut.

72. Dry Annealing.—The process known as **dry annealing** is very effective. It consists of heating the steel to a medium red and then packing it in hot sand, hot, dry ashes, or powdered air-slacked lime, and then allowing it to cool slowly. If the steel is allowed to soak in the fire or if it is heated above a medium red, it may be spoiled.

73. Water Annealing.—By **water annealing,** small pieces of steel can be very effectively annealed in a short time. The steel is heated to a dull red, and allowed to cool down to almost black heat in the hot ashes. It is then plunged into water, brine, or strong soapsuds.

74. Annealing Steel Castings or Forgings.—Steel forgings and castings are frequently annealed by putting them into a heating furnace where they are heated to a dull red, and then cooled slowly by closing the furnace doors tightly and allowing the fire to go out. The pieces will then cool off with the furnace, which holds its heat for a number of days.

ANNEALING WROUGHT IRON.

75. General Remarks.—Although wrought iron is normally fibrous in its structure, under certain conditions its structure becomes decidedly crystalline. Suddenly chilling it from a red heat or subjecting it to jarring or vibrations will cause it to crystallize. The bolts in bridges often snap off because the continual strain and vibration have crystallized the iron. The chains used in shops for lifting heavy loads are often known to snap with a load that another chain of the same size will carry with perfect safety. The difference in the carrying capacities between the two is due to the difference in their structures. The fibrous structure of the iron can be restored, however, by annealing.

For this reason all chains, rings, and hooks subjected to great strains should be annealed occasionally to restore the fibrous structure to the iron. This should be done once a year, just before the cold weather sets in.

76. Method of Annealing.—To anneal the chains, they are slowly raised to a cherry-red heat and held at that heat for some time. They are then buried in hot sand or ashes and allowed to cool slowly.

A very effective way is to heat the iron to a red heat slowly in a furnace and then allow the fire to go out, closing the furnace tightly. This is generally done toward the close of the week and the iron taken out on Monday morning. Large forgings are frequently annealed in this way, often requiring a number of days or even weeks to cool. The pieces are often packed in iron ore, which gives the forging an even bearing and thus avoids the danger of its warping or sagging from its own weight while hot. Steel must not be bedded in iron ore, as this would decarbonize it.

BLACKSMITHING AND FORGING.

(PART 4.)

FORGING MACHINES.

1. Classification.—In many instances, the blows that a man can strike will not produce the desired effect on iron; or in other instances, this method of shaping the metal may be too costly. In such cases, forging machines are resorted to. These machines may be divided into two classes; namely, machines that shape the iron by hammering it and those that shape it by exerting a steady pressure upon it. The first class, commonly called *hammers*, includes drop hammers, trip hammers, steam hammers, etc.; the second class, called *presses*, comprises such machines as punches, shears, forming presses, bulldozers, etc.

HAMMERS.

2. Early Forms.—The earlier forms of machine hammers have heads that run in guides or are attached to the ends of levers. The head is raised by hand or by power, and then allowed to drop, the intensity of the blow varying with the weight of the head and the height from which it falls. Formerly, machine hammers were generally driven by water-power, the head being fastened to the end of a

lever that was raised by means of cogs set on a shaft and driven by a waterwheel. This form of hammer is now little used.

3. Rubber-Cushioned Hammer.—Fig. 1 shows a style of hammer in which the shaft is driven by a belt *b*. A crank on the shaft operates a lever that lifts the rubber buffer *r* and at the same time depresses the rubber buffer *s*, thus raising the lever *l*; as the crank continues to turn, it

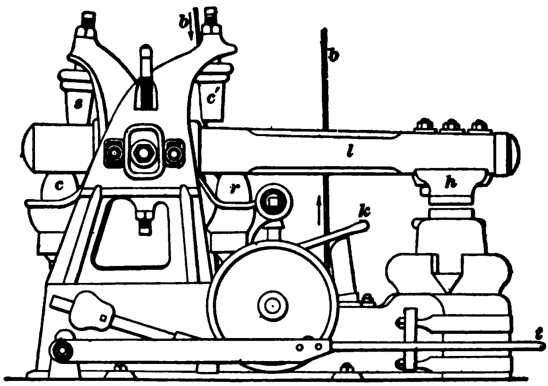

FIG. 1.

lets down the lever and the elasticity of the buffers *c* and *c'*, together with the weight of the hammer *h*, causes the hammer to descend and strike a blow. The treadle *t* and the hand lever *k* operate a clutch by which the machine is started and stopped. The rubber buffers help to cushion the blow.

4. Forging Hammer.—Another type of hammer is shown in Fig. 2. The pulley *p* is driven by a belt *n* that runs continuously, but which is so loose that it does not turn the pulley unless a tightener is pressed against it. This tightener, pulley *f*, is operated by the treadle *k*. The head *h* is raised by the crankpin *c*, which is fastened in the slot *r*. The pin *c* may be set anywhere in the slot *r*, and the length of the stroke varied accordingly.

5. Steam Hammer.—In the steam hammer, Fig. 3, the head *h* is keyed on the end of a piston that works in a steam cylinder. Admitting steam into the lower end of the cylinder raises the head, while admitting steam into the upper end of the cylinder causes the hammer to descend by its own weight in addition to the pressure of the steam on

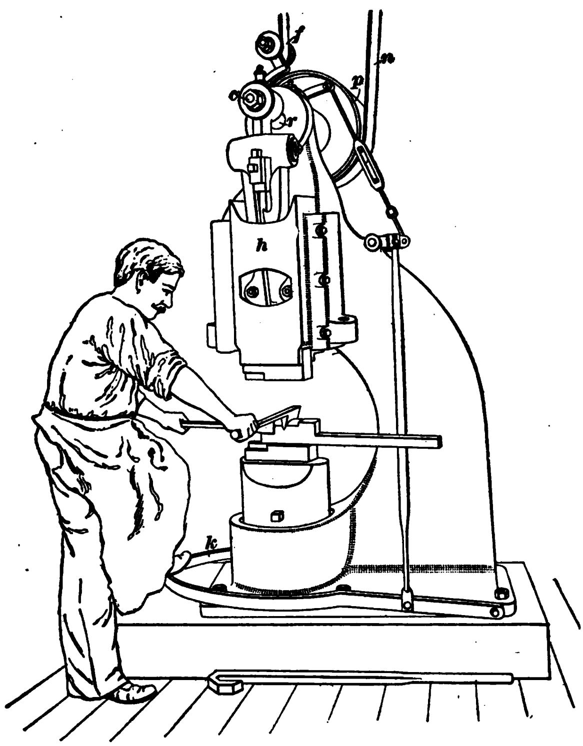

FIG. 2.

the upper face of the piston. The length of the stroke is regulated by means of a valve, which may be set so as to make the hammer strike single blows in accordance with the movements of the lever *l*; or the hammer may be set to strike blows automatically in rapid succession, the force of the blows being regulated with great precision by the valve.

6. Friction-Board Drop Hammer.—Fig. 4 shows a friction-board drop hammer. The head *h* is raised by the board *b* that runs between two friction rollers *k* at the top of the machine. The friction rollers run continuously, and by moving the lever *l* or the treadle *f* downwards, the rod *r* is moved upwards. By means of the cam *c*, the rollers are brought closer together and, clutching the board, raise

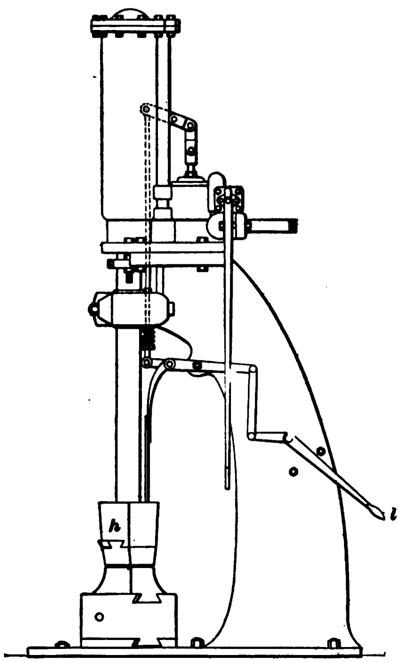

FIG. 3.

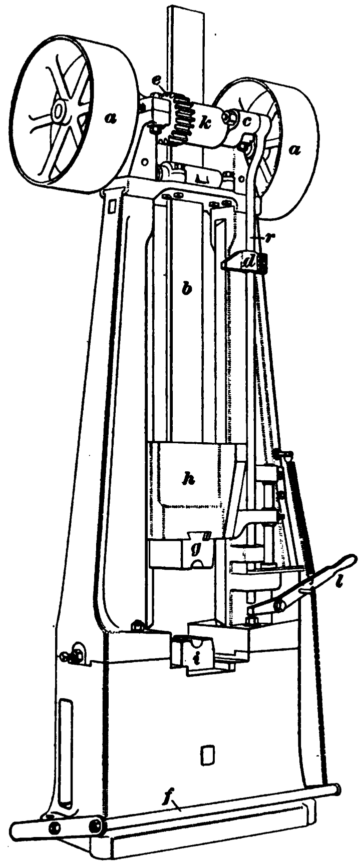

FIG. 4.

it with the head. When the lever or treadle is released, the rollers release the board and the head falls and strikes a blow. The cam *c* may be moved automatically by means of the dog *d*, which is set at a suitable position on the rod *r*. By this arrangement, the hammer may be made to

strike continuous blows as the dog *d* throws the cam whenever the head reaches it. As the force of the blow depends on the height from which the hammer falls, the blow can be varied by changing the position of the dog *d*.

DROP FORGING.

7. General Consideration.—When a number of forgings of the same pattern is to be made, the work is generally done by driving or pressing the iron into a die placed

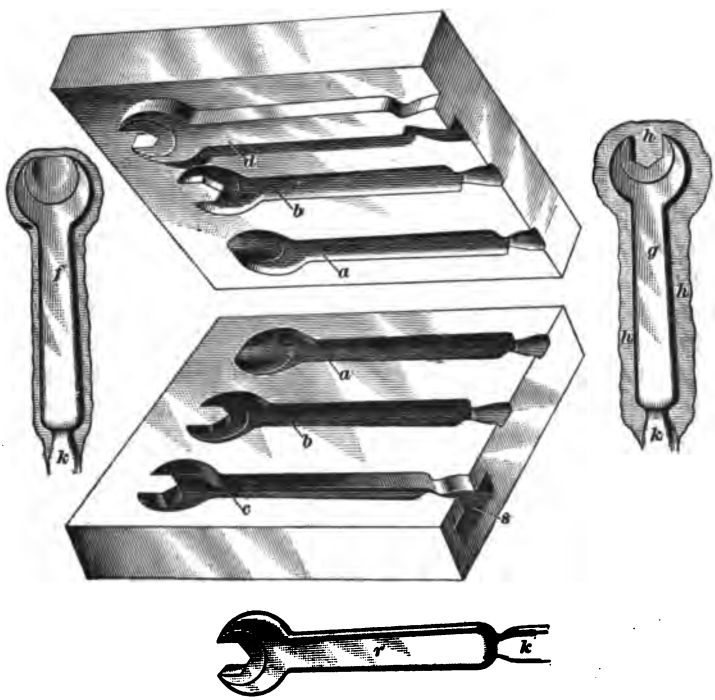

FIG. 5.

under a drop hammer. This method is called **drop forging.** Much of this class of work is now done by steam hammers and forging presses, but the finished product still retains the name of drop forging. Work of this description

is frequently shaped by several sets of dies before it has acquired the desired form, or the work is roughly formed by hand and then finished in the dies.

8. Dies for Drop Forging.—Fig. 5 shows a set of dies that may be used in drop forging the wrench shown in Fig. 6. The end of a bar of iron is upset to gain stock for the head of the wrench; this may be done by hand or in a machine. The bar is then put into the first die *a*, which acts like a fuller and spreads the iron at the point out toward the edges. The handle is partly formed in this die. The partly finished piece, which is shown at *f*, is then put into the second die *b* and the handle finished and the metal in the head pressed well into the die. When the forging is taken from this die it has the form *g* of the finished wrench, but the fin of metal *h* which squeezed out of the die is still attached to it. This fin is sheared off by the trimming die *c*, which is really a punch, the portion *d* fitting into the die *c* for this purpose. The end *k* is left on and serves as a handle for the wrench during the operation. When trimmed, the wrench *r* falls into the pocket in the bottom of the die and is pulled out through the slot *s*. The end *k* is finally cut off on a shear and the edges finished to the form shown in Fig. 6 by grinding them upon an emery wheel.

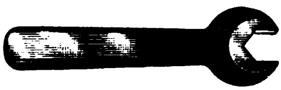

FIG. 6.

PRESSES.

9. General Consideration.—As previously stated, machines that form iron into shape by a steady pressure are called **presses.** Although iron is generally worked hot, still there are cases in which it can be worked cold with greater advantage. This is especially true with such presses as punches, shears, and some forms of bending machines.

10. Small Presses.—Small foot-power or hand-geared presses are sometimes used for punching, shearing, and

bending. They are serviceable only for light work and where the work is done in small quantities.

11. Multiple Forging Machine.—A machine having a number of pitmans, each carrying a die shaped for forming a round or flat section, is shown in Fig. 7. The bar of iron is placed between a set of these dies and drawn down to the size of this die; after which it is placed between the next set and

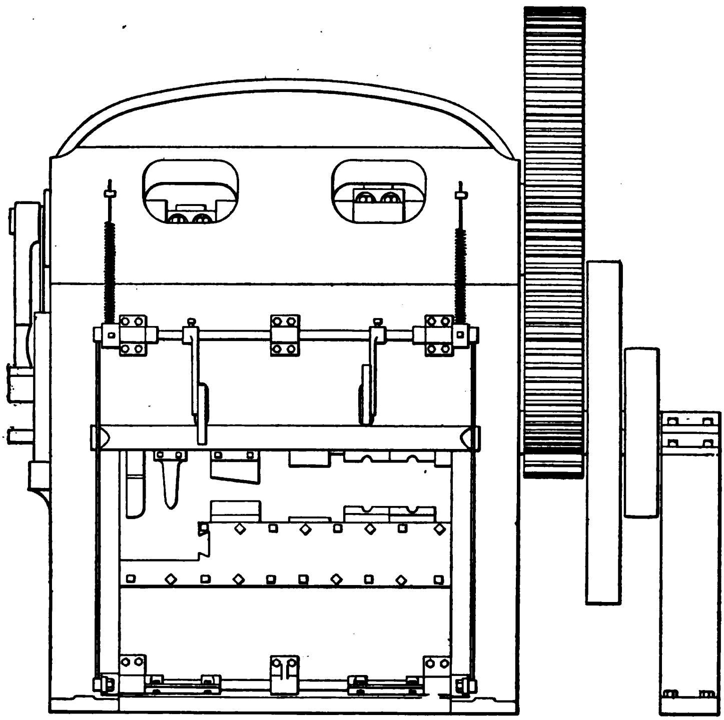

FIG. 7.

drawn down to that size; and so on until it is of the size required. Or, bars may be drawn down to flat sizes between two flat dies which may be set to the two sizes required for width and thickness, or different sections may be formed on the same bar.

12. Bulldozer.—The bulldozer, Fig. 8, is really a horizontal forming press that is used for bending iron into the required shape by a single stroke. The piece is placed between two dies, one of which *a* is stationary, while the other *b* slides on horizontal guides. Connecting-rods *c*, *c*, one on each side of the machine, move the crosshead *d* to which is attached the die *b*.

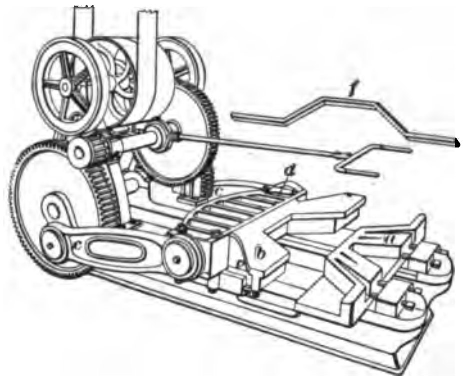

FIG. 8.

The machine may be driven by means of a belt, as in the illustration, or by a motor or engine on the machine; also, the dies may be readily changed. The form *f* shows a piece of iron bent into shape with the dies shown in the machine.

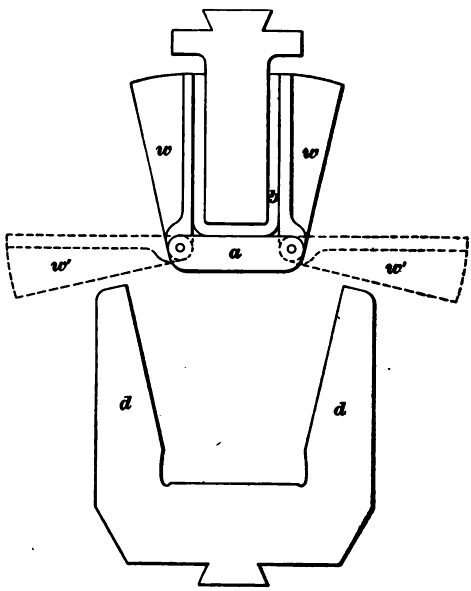

FIG. 9.

13. Air-Power Bulldozer.—A very convenient form of bulldozer is driven by compressed air. The movable die is keyed to a crosshead and forced forwards by the admission of compressed air into a

cylinder. The machine is sometimes placed upon a truck so that it can be moved about and is used for light work.

14. Special Bulldozer Die.—Fig. 9 shows a form of die that is admirably adapted for use in a bulldozer. The wings *w*, *w* of the die *a* are folded up by the die *d*, thus bending the iron without stretching it. The part *d* acts simply as a cam to move the wings of the die. The illustration shows a piece *b*, with the wings *w*, *w* closed about it; the dotted lines *w'*, *w'* show the position of the wings when the die is open.

HEATING FURNACES.

FURNACES FOR LIGHT WORK.

15. Small Coke Furnace.—For heating material to be worked under drop hammers or in forging machines, a small coke furnace, similar to that illustrated in Fig. 10, is

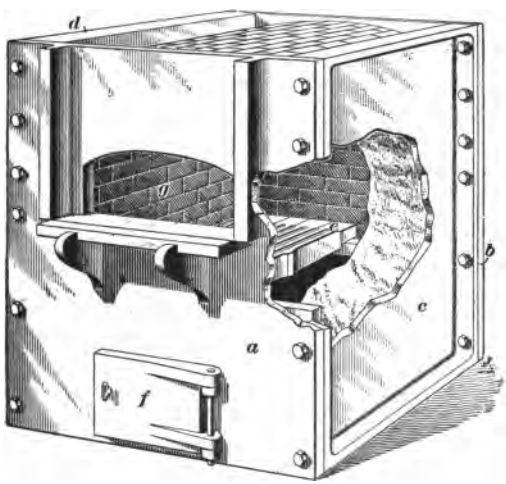

FIG. 10.

frequently used. In this style the body of the furnace is made up of iron castings, the front and back castings *a* and *b*

being bolted to the side castings *c* and *d*. The fire is supported on the grate bars at *e* and the furnace lined with fire-brick, as shown. The ashes are removed through a door at *f* and a suitable blast is usually maintained in the space below the grate. A bed of coke is kept on the grate bars at *e* and the material to be heated is laid on it through the opening *g*. This opening is provided with a suitable door so balanced by weights that it can be raised or lowered. The door is raised while the work or coke is being put into the furnace, but after the pieces are in place the door is let down in order to prevent a rush of cold air over the top of the fire. The door at *g* is generally brick-lined and may be water-jacketed. It can be suspended by any convenient arrangement of levers or chains and provided with a counter-balance. The waste gases escape through an opening in the back of the furnace.

16. Gas-Fired and Oil-Fired Furnaces.—Very frequently gas-fired and oil-fired furnaces are used for heating work for small forging machines. The furnace consists of a simple muffle or combustion chamber in which the work is laid and into which a spray of oil mixed with the proper amount of air, or a stream of gas mixed with the proper amount of air, is introduced and burned. The furnace is usually provided with an adjustable door similar to that used on the furnace shown in Fig. 10.

FURNACES FOR HEAVY WORK.

17. Description.—Furnaces that are to be used for heating heavy pieces, such as are to be worked in large forging machines, are generally of the type known as *reverberatory furnaces;* in this type the heat is reflected upon the work from the top of the furnace. This result is obtained by arching the ceiling of the furnace, thus causing the heated gases to pass over the top of the work. Besides this, the heated ceiling radiates its heat downwards in nearly

the same manner that a concave mirror reflects the light toward its focus. As the heat in the furnace is very great, all parts with which the heated gases come into contact are built of firebrick laid in fireclay. The part of the hearth that is nearest to the outlet flue is generally built with a pitch toward the outlet that enables the slag produced in the furnace to flow toward the lowest point in the flue, or the stack, from which point it can be drawn off through the slag hole.

18. Fuels.—Coal, oil, or gas may be used as fuel in these furnaces, but good bituminous coal is the fuel generally used. The blast is regulated to suit the conditions and requirements. The iron or steel heated in these furnaces does not come in contact with the fuel.

19. Reverberatory Furnace.—Figs. 11, 12, 13, and 14 illustrate a heating furnace that is used for heating iron for a steam hammer. Fig. 11 shows a longitudinal

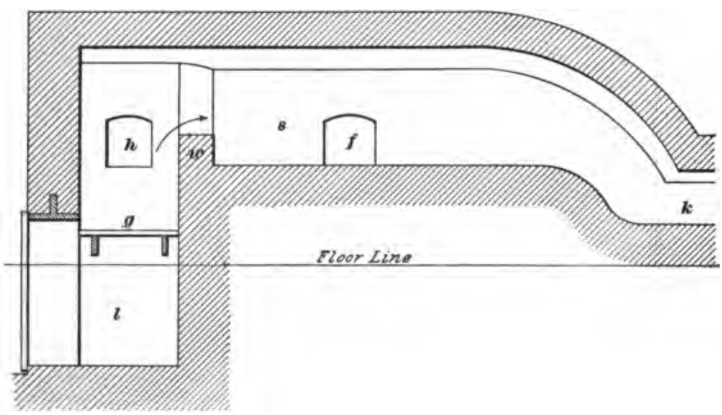

FIG. 11.

section through the furnace. The grate is situated at *g* and the fire-door *h* at the end of the combustion chamber that is in the side of the furnace. The heat passes over the bridge wall *w* through the heating chamber *s* and out

through the flue *k* into the stack. The ash-pit is shown at *l*. A plan of the furnace is shown in Fig. 12, a side view in

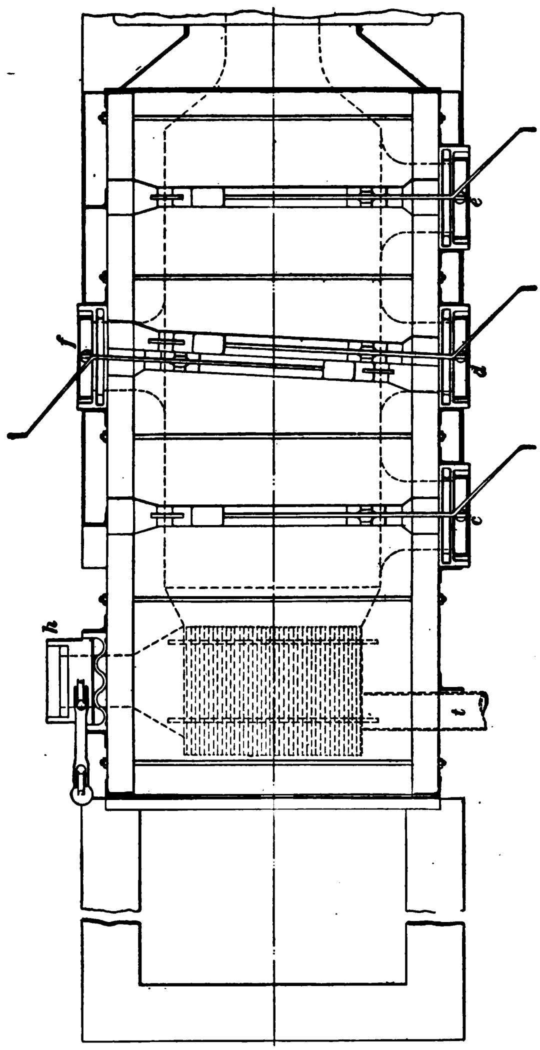

FIG. 12.

Fig. 13, an end view in Fig. 14 (*a*), and a cross-section in Fig. 14 (*b*).

The illustrations show that the furnace has three doors *c*, *d*, and *e* on one side and one door *f* on the side opposite the

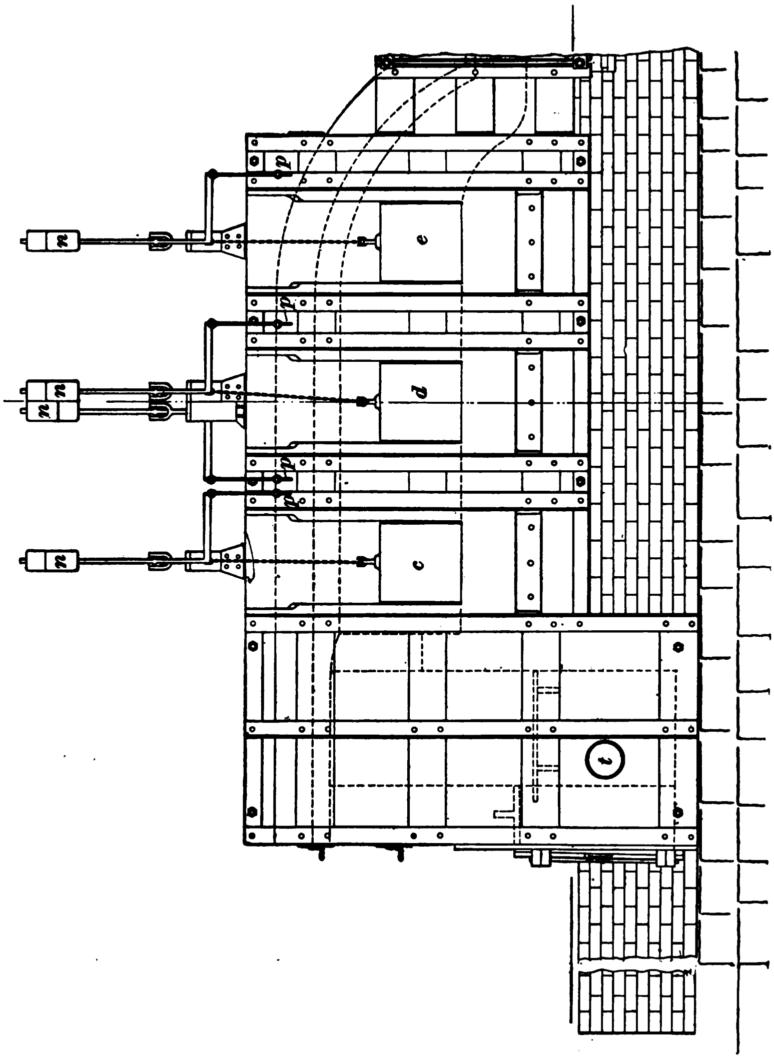

FIG. 18.

door *d*. This is for handling long pieces that can be allowed to project through the doors on both sides. The

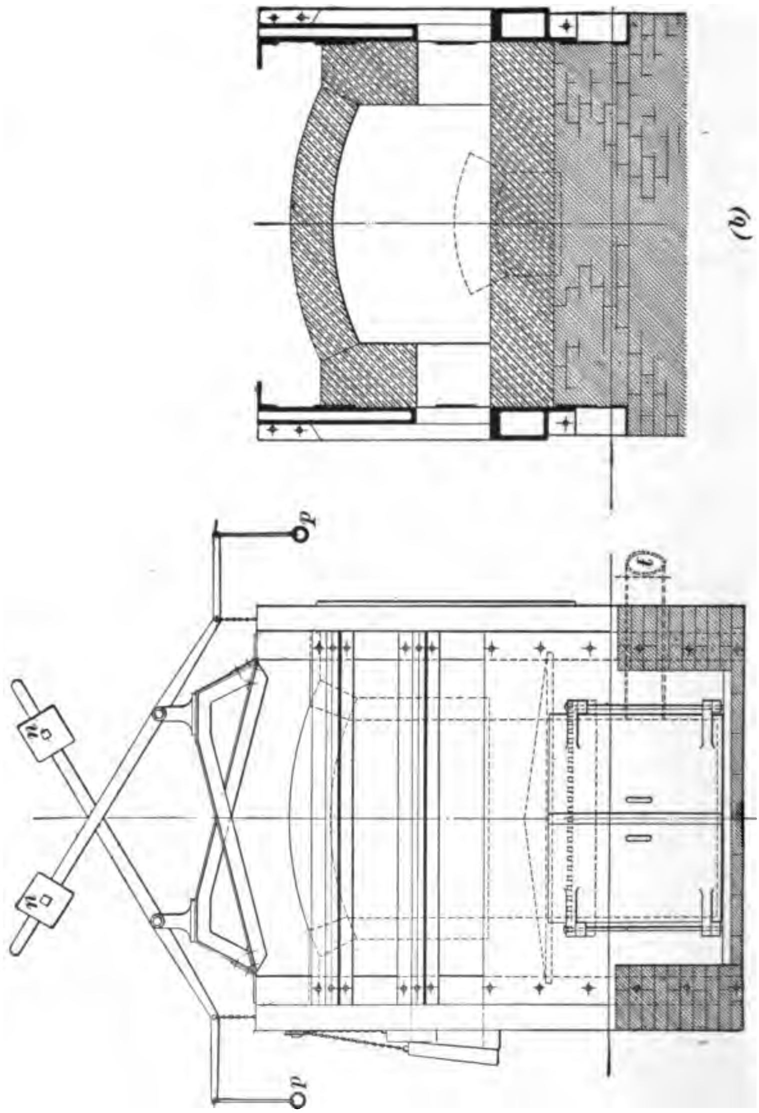

FIG. 14.

fire-door *h* is on the same side as the door *f*. The doors are counterbalanced by the weights *n*, *n*, and are raised and lowered by means of the handles *p*, *p*. A bed of sharp sand mixed with clay or of coarse molding sand is spread over the hearth and the iron laid upon this. A reducing fire is maintained to prevent oxidizing the iron.

20. The slag formed during the welding and fagoting processes is drawn out through a slag hole in the bottom of the stack or at the lowest point of the flue. All the brickwork with which the heat comes into contact is built of or lined with firebrick laid in fireclay. The blast pipe *t* opens into the ash-pit, and a blast of from 8 to 12 ounces is maintained, according to circumstances. The stack is about 22 inches square.

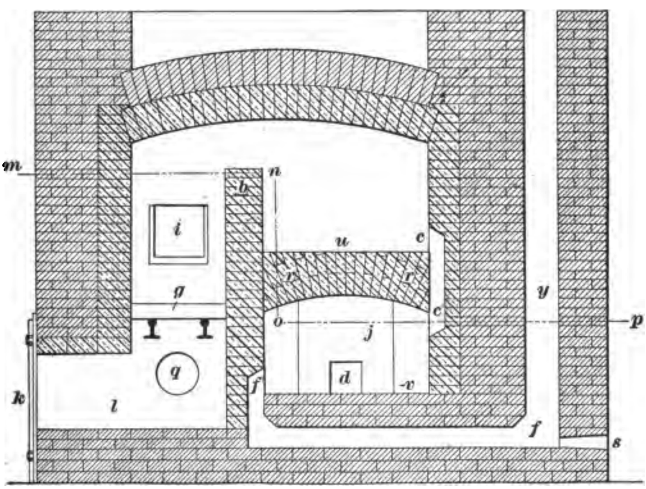

FIG. 15.

Some furnaces have the counterbalance levers and weights at the side, thus leaving the top of the furnace clear. A boiler is frequently set above the furnace and the waste heat from the furnace passed underneath it and then through the flues of the boiler before going into the stack.

In this way the waste heat can be utilized to produce the steam required in the smith shop for steam hammers, engines for driving fans, etc.

21. Double-Deck Reverberatory Furnace.—Fig. 15 shows a longitudinal section through a furnace used for case-hardening and annealing and also for heating iron for forging and for tempering. Fig. 16 shows a horizontal section through *m n o p*, Fig. 15. The furnace has an upper and a lower hearth. The upper hearth *u*, being nearer the

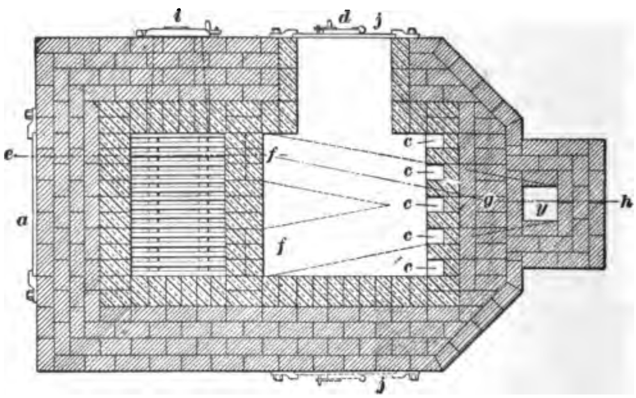

FIG. 16.

grate *g* and, therefore, the hotter, is used for tempering or for heating iron for forging, while the lower hearth *v*, being slower to heat, is used for annealing or case-hardening. The doors *j* to the hearths are on opposite sides of the furnace and slide in vertical cast-iron guides.

The weight of the door is counterbalanced by a weight *w*, as shown in Fig. 17. Each door has a small door *d* (Fig. 17) hinged to it, through which the heat can be watched or small pieces handled. The fire-door *i* is set at the end of the grate and on the side of the furnace, as the fire can be spread more evenly if it is set in this way, and the heat against the bridge wall will be more evenly distributed.

The door *k* to the ash-pit *l* is at the front end of the furnace. The heat passes over the bridge wall *b*, through the upper hearth, thence through the flues *c*, *c* into the lower hearth. The flues *c*, *c* are 4 inches by 4 inches in size and 4 inches of brickwork is left between them to support the end of the arch *r*. From the lower hearth, the heat enters two flues *f*, *f*, one at each side of the hearth, which, later, converge into one large flue that opens into the bottom of the stack *y*. The blast pipe *q* opens into the end of the ash-pit and a slag hole *s* is generally left in the bottom of the stack.

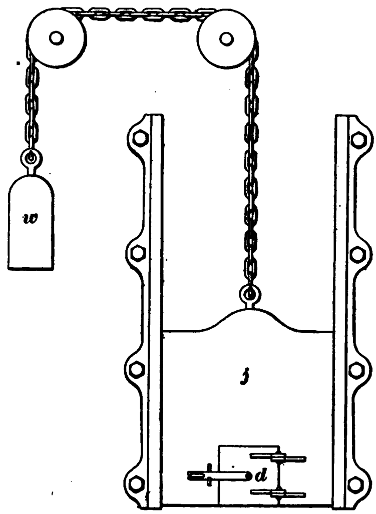

FIG. 17.

HANDLING DEVICES.

22. Handling appliances are necessary for such heavy work as requires a steam hammer in its forging. If the loads must be frequently carried between the same points, the hoist block may be suspended from a trolley running on an overhead rail *r*, as shown in Fig. 18. In this illustration, the portion of the track between *a* and *b* serves as a switch, and its position is regulated from the floor by means of the handles *c*, *c*. The traveling carriage is shown at *d*, and the differential chain pulley is shown at *e*. By putting switches into the rails and branches leading to the places where the hoist is needed, the efficiency is greatly increased. These switches must have a guard to prevent derailing the trolley, or a lock to make it impossible to turn the switch when the trolley is on one of the branches.

23. Jib Crane.—A jib crane, shown in Fig. 19, is another convenient device for handling heavy pieces. Swinging in the arc of a circle, it completely controls the included space.

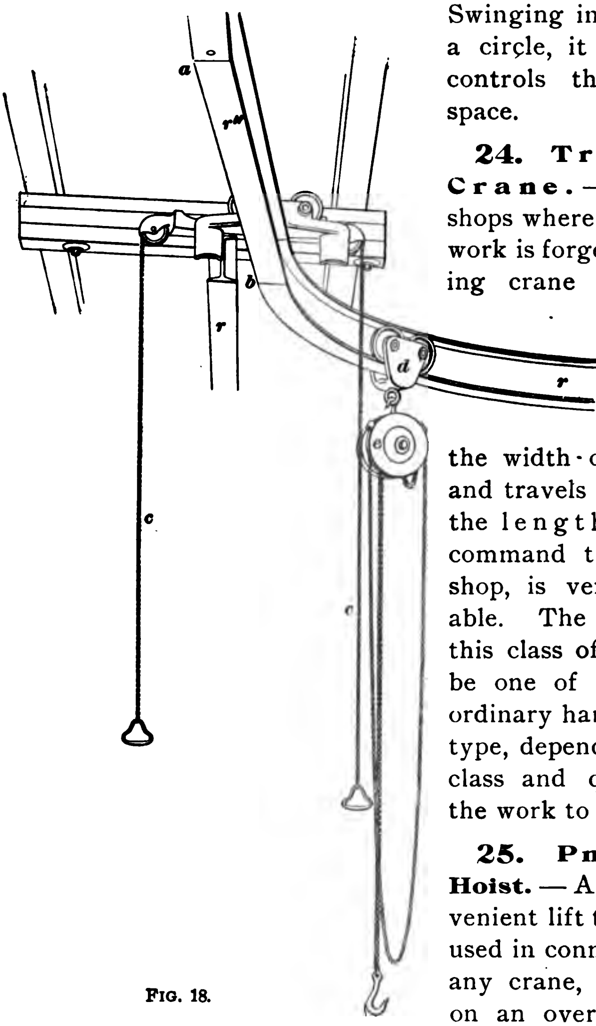

FIG. 18.

24. Traveling Crane.—In smith shops where very heavy work is forged, a traveling crane that spans the width of the shop and travels throughout the length, so as to command the entire shop, is very serviceable. The crane for this class of work may be one of any of the ordinary hand or power type, depending on the class and quantity of the work to be handled.

25. Pneumatic Hoist.—A very convenient lift that may be used in connection with any crane, or directly on an overhead track, is the pneumatic hoist, a form of which is shown in Fig. 20. It consists of a cylinder *c* that has a piston moving upwards and downwards within it; a rod *r*, having an eye *e* in its lower end, is attached to the piston. Compressed air

from a pipe p is admitted into the lower end of the cylinder through the three-way valve v, and may be discharged into the outer air from the cylinder through the same valve. Pulling the hand chain on one end of the

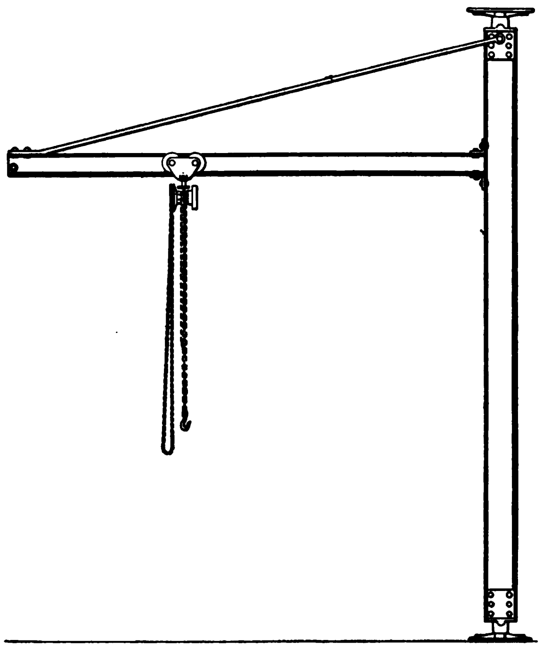

FIG. 19.

controlling lever admits the compressed air, forcing the piston upwards in the cylinder and lifting the load attached to the eye; pulling the chain attached to the other end causes the discharge of the compressed air from the cylinder and lowers the load.

26. Relative Advantages of Handling Devices. The stationary differential chain block or pneumatic hoist can be used only at one point, but when it is suspended from a trolley running along a ceiling rail, its efficiency is extended to all points on the floor under the rail. By the

use of switches, sidings, etc., this field of usefulness may be greatly increased; nevertheless, it will require a very complicated system of switches to make this form of lifting and conveying thoroughly efficient even for a comparatively small space. The jib crane gives absolute control over the space it covers, which is a circle having its center at the standard of the crane, and by using several jib cranes the work may be passed from one to the other. The traveling crane, however, makes it possible to reach any point of the space between the rails.

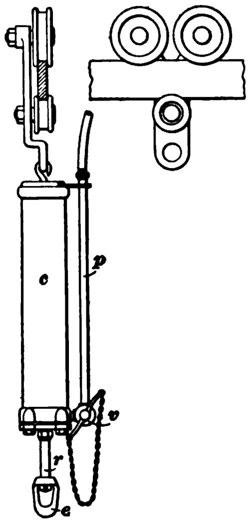

FIG. 20.

RIVETING.

27. General Remarks.—It is frequently necessary to fasten two pieces of iron together where a weld cannot be made and where soldering would not be strong enough or where it would be inconvenient. In such a case, **riveting** is generally resorted to. Holes are punched through both pieces and a **rivet,** which is a pin having a head at one end, is put through the holes in both pieces and the plain end upset so as to form a second head. Riveting may be done cold, but if a tight joint is required the rivet is heated and headed while hot. In cooling it will contract and draw the heads together, thus making the joint tighter. The holes for riveting are generally punched. This makes them slightly tapering, and if two punched plates are brought together the holes may come together in three different ways, as are shown in Fig. 21, (*a*), (*b*), and (*c*). If the rivets are hot enough, they will fill the holes in any case, but passing them through the cold plates frequently chills them so that they will not upset sufficiently to do this. For this

reason the holes should always be drifted, or, better still, reamed out after the plates have been clamped in position, as shown in Fig. 21 (*d*). The *drift pin* is a smooth, slightly tapered pin that is driven into the holes to expand them in places where they are too small, thus giving them an even taper. The reamer accomplishes the same result by cutting away the projecting metal. The hot rivet is then put into the hole and a heavy piece of iron or a hammer is held against the head while the point has the second head formed upon it. The body of the rivet should completely fill the holes in the plates.

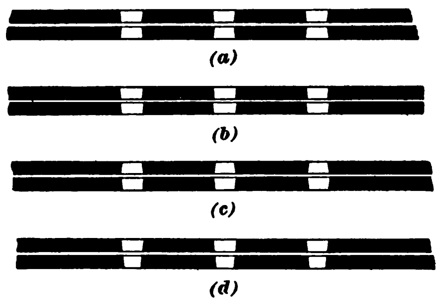

FIG. 21.

28. Riveting Machines.—Where a large number of rivets is to be headed, the work is done by machinery, which does it much faster and, therefore, better than can be done by hand, because the rivet is headed before it has had time to cool. The plunger of the riveting machine is sometimes driven by compressed air at the rate of several hundred blows per minute, and in upsetting iron, for riveting is nothing but upsetting, the velocity of the blows counts far more than does their weight. In forming the head, sharp blows with a light hammer upset and spread the iron, while heavy blows tend to bend it. Another form of riveting machine presses the end of the rivet into a head by forcing a forming die against it. These machines are generally driven by compressed air or by hydraulic pressure, and give satisfactory results, as the flow of the metal under pressure completely fills the rivet holes. In taking riveted plates apart, it is better to drill the rivets out than to drive them through.

MISCELLANEOUS.

CASE-HARDENING CAST IRON.

29. Solution for Case-Hardening Cast-Iron Dies. Dies, etc., made of cast iron may be case-hardened by heating them to a cherry red and then chilling them in the following solution: 1 quart oil of vitriol, 4 pecks of salt, 8 pounds of alum, 1 pound yellow prussiate of potash, 1 pound cyanide of potash, 2 pounds saltpeter, which ingredients have been dissolved and mixed in 40 gallons of water, the cyanide of potash and yellow prussiate of potash being dissolved in hot water and the others in cold. If one heating and chilling does not harden the die enough, the process may be repeated.

STRETCHING IRON.

30. Shrinking.—Heating a body of metal expands it. The blacksmith makes use of this fact in shrinking on bands, hoops, collars, etc. The ring or collar to be shrunk on is heated to an even red heat, then slipped into its place and cooled. Iron stretches about $\frac{1}{8}$ inch to the foot when heated from a normal temperature to a medium-red heat.

31. Peening.—Iron may be stretched by *peening* it; that is, by striking it with the peen of a hammer. This method is often used to loosen a collar or a nut. A little benzine or kerosene poured into the joint will loosen any rust that may be between the surfaces.

RUST JOINT.

32. If it is desired to cement a hole or crack in iron, it can be done by ramming into the hole the following mixture as soon as prepared: 5 pounds of cast-iron borings and 2 ounces of sal ammoniac that have been made into a thick paste by the addition of water. If only 1 ounce of sal ammoniac is used, the cement will set slower but it will be stronger.

TABLES.

TEMPERATURES.

33. The temperatures given in Table I have been adopted as standards in work conducted at the plant of the Bethlehem Steel Company, South Bethlehem, Pennsylvania, by Messrs. Taylor and White, who have carried on quite extensive experiments in regard to temperatures.

TABLE I.

TEMPERATURES CORRESPONDING TO VARIOUS COLORS.

Color.	Temperature. Degrees F.
Dark blood red, black red	990°
Dark red, blood red, low red	1,050°
Dark cherry red	1,175°
Medium cherry red	1,250°
Cherry, full red	1,375°
Light cherry red, bright cherry red, scaling heat,* light red	1,550°
Salmon, orange, free-scaling heat	1,650°
Light salmon, light orange	1,725°
Yellow	1,825°
Light yellow	1,975°
White	2,200°

* Heat at which scale forms and adheres, i. e., does not fall away from the piece when allowed to cool in air.

34. The following tables will be found of use in the various calculations necessary in the smith shop. Table II gives the weight of square and round-rolled wrought-iron bars; Table III, the weight of flat bar iron; Table IV, the weight of sheet iron; and Table V, the weight of a given volume of different metals in common use.

TABLE II.

WEIGHT OF SQUARE AND ROUND-ROLLED WROUGHT IRON 1 FOOT IN LENGTH.

Side or Diameter. Inches.	Weight of Square Iron. Pounds.	Weight of Round Iron. Pounds.	Side or Diameter. Inches.	Weight of Square Iron. Pounds.	Weight of Round Iron. Pounds.
$\frac{1}{16}$	.013	.010	$4\frac{3}{8}$	64.700	50.810
$\frac{1}{8}$	.053	.041	$\frac{1}{2}$	68.450	53.760
$\frac{3}{16}$	.118	.093	$\frac{5}{8}$	72.300	56.790
$\frac{1}{4}$	211	.165	$\frac{3}{4}$	76.260	59.900
$\frac{3}{8}$	.475	.373	$\frac{7}{8}$	80.330	63.090
$\frac{1}{2}$	.845	.663	5	84.480	66.350
$\frac{5}{8}$	1.320	1.043	$\frac{1}{8}$	88.780	69.730
$\frac{3}{4}$	1.901	1.493	$\frac{1}{4}$	93.170	73.170
$\frac{7}{8}$	2.588	2.032	$\frac{3}{8}$	97.660	76.700
1	3.380	2.654	$\frac{1}{2}$	102.240	80.300
$\frac{1}{8}$	4.278	3.359	$\frac{5}{8}$	106.950	84.000
$\frac{1}{4}$	5.280	4.147	$\frac{3}{4}$	111.750	87.770
$\frac{3}{8}$	6.390	5.019	$\frac{7}{8}$	116.670	91.630
$\frac{1}{2}$	7.604	5.972	6	121.660	95.550
$\frac{5}{8}$	8.926	7.010	$\frac{1}{4}$	132.040	103.700
$\frac{3}{4}$	10.352	8.128	$\frac{1}{2}$	142.820	112.160
$\frac{7}{8}$	11.883	9.333	$\frac{3}{4}$	154.010	120.960
2	13.520	10.620	7	165.630	130.050
$\frac{1}{8}$	15.263	11.990	$\frac{1}{4}$	177.670	139.540
$\frac{1}{4}$	17.112	13.440	$\frac{1}{2}$	190.140	149.330
$\frac{3}{8}$	19.066	14.980	$\frac{3}{4}$	203.020	159.460
$\frac{1}{2}$	21.120	16.590	8	216.330	169.860
$\frac{5}{8}$	23.292	18.290	$\frac{1}{4}$	230.060	180.700
$\frac{3}{4}$	25.560	20.080	$\frac{1}{2}$	244.220	191.810
$\frac{7}{8}$	27.939	21.940	$\frac{3}{4}$	258.800	203.260
3	30.416	23.890	9	273.790	215.040
$\frac{1}{8}$	33.010	25.930	$\frac{1}{4}$	289.220	227.150
$\frac{1}{4}$	35.704	28.040	$\frac{1}{2}$	305.060	239.600
$\frac{3}{8}$	38.500	30.240	$\frac{3}{4}$		252.380
$\frac{1}{2}$	41.408	32.510	10		265.400
$\frac{5}{8}$	44.420	34.890	$\frac{1}{4}$		278.920
$\frac{3}{4}$	47.534	37.330	$\frac{1}{2}$		292.690
$\frac{7}{8}$	50.760	39.860	$\frac{3}{4}$		306.800
4	54.080	42.460	11		321.220
$\frac{1}{8}$	57.510	45.170	$\frac{1}{4}$		336.000
$\frac{1}{4}$	61.050	47.950	$\frac{1}{2}$		351.100

TABLE III.

WEIGHT OF A LINEAL FOOT OF FLAT BAR IRON IN POUNDS.

Breadth. Inches.	Thickness in Fractions of Inches.								
	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	$\frac{7}{8}$	1
1	.83	1.04	1.25	1.46	1.67	2.08	2.50	2.92	3.34
$1\frac{1}{8}$	.93	1.17	1.40	1.64	1.87	2.34	2.81	3.28	3.75
$1\frac{1}{4}$	1.04	1.30	1.56	1.82	2.08	2.60	3.13	3.65	4.17
$1\frac{3}{8}$	1.14	1.43	1.72	2.00	2.29	2.87	3.44	4.01	4.59
$1\frac{1}{2}$	1.25	1.56	1.87	2.19	2.50	3.13	3.75	4.38	5.00
$1\frac{5}{8}$	1.35	1.69	2.03	2.37	2.71	3.39	4.07	4.70	5.43
$1\frac{3}{4}$	1.46	1.82	2.19	2.55	2.92	3.65	4.38	5.11	5.84
$1\frac{7}{8}$	1.56	1.95	2.34	2.74	3.13	3.92	4.69	5.47	6.26
2	1.67	2.08	2.50	2.92	3.34	4.17	5.01	5.86	6.68
$2\frac{1}{8}$	1.77	2.21	2.66	3.10	3.55	4.43	5.32	6.21	7.10
$2\frac{1}{4}$	1.87	2.34	2.81	3.28	3.76	4.69	5.63	6.57	7.52
$2\frac{3}{8}$	1.98	2.47	2.97	3.47	3.96	4.95	5.95	6.94	7.93
$2\frac{1}{2}$	2.08	2.60	3.13	3.65	4.17	5.21	6.26	7.30	8.35
$2\frac{5}{8}$	2.19	2.74	3.28	3.83	4.38	5.47	6.57	7.67	8.77
$2\frac{3}{4}$	2.29	2.87	3.44	4.01	4.59	5.74	6.88	8.03	9.18
$2\frac{7}{8}$	2.40	3.00	3.60	4.20	4.80	6.00	7.20	8.40	9.60
3	2.50	3.13	3.75	4.38	5.01	6.26	7.51	8.76	10.02
$3\frac{1}{4}$	2.71	3.39	4.07	4.74	5.43	6.78	8.14	9.49	10.86
$3\frac{1}{2}$	2.92	3.65	4.38	5.11	5.84	7.30	8.76	10.23	11.69
$3\frac{3}{4}$	3.13	3.91	4.68	5.47	6.26	7.82	9.39	10.95	12.52
4	3.34	4.17	5.00	5.84	6.68	8.35	10.02	11.69	13.36
$4\frac{1}{4}$	3.54	4.43	5.32	6.21	7.09	8.87	10.64	12.42	14.19
$4\frac{1}{2}$	3.75	4.69	5.63	6.57	7.51	9.39	11.27	13.15	15.03
$4\frac{3}{4}$	4.06	4.95	5.94	6.94	7.93	9.91	11.89	13.88	15.86
5	4.17	5.21	6.26	7.30	8.35	10.44	12.52	14.61	16.70
$5\frac{1}{4}$	4.38	5.47	6.57	7.67	8.76	10.96	13.14	15.34	17.53
$5\frac{1}{2}$	4.59	5.73	6.88	8.03	9.18	11.48	13.77	16.07	18.37
$5\frac{3}{4}$	4.80	6.00	7.20	8.40	9.60	12.00	14.40	16.80	19.20
6	5.01	6.25	7.51	8.76	10.02	12.53	15.03	17.53	20.05

TABLE IV.

WEIGHT OF SHEET AND PLATE IRON.

Thickness by Birmingham Wire Gauge and Inches—Weight of a Square Foot in Pounds.

Thickness.		Weight. Pounds.	Thickness.		Weight. Pounds.
B. W. Gauge.	Part of an Inch.		B. W. Gauge.	Part of an Inch.	
36	.00400	.126	11	.12000	4.480
35	.00500	.202		$\frac{1}{8}$ or .12500	5.054
34	.00700	.283	10	.13400	5.426
33	.00800	.322	9	.14800	5.980
32	.00900	.364		$\frac{5}{32}$ or .15620	6.305
31	.01000	.405	8	.16500	6.605
30	.01200	.485	7	.18000	7.270
29	.01300	.526		$\frac{3}{16}$ or .18750	7.578
28	.01400	.594	6	.20300	8.005
27	.01600	.677		$\frac{7}{32}$ or .21870	8.790
26	.01800	.755	5	.22000	8.912
25	.02000	.811	4	.23800	9.620
24	.02200	.912		$\frac{1}{4}$ or .25000	10.090
23	.02500	1.078	3	.25900	10.370
22	.02800	1.137		$\frac{9}{32}$ or .28120	11.380
	$\frac{1}{32}$ or .03125	1.259	2	.28400	11.525
21	.03200	1.310	1	.30000	12.150
20	.03500	1.416		$\frac{5}{16}$ or .31250	12.580
19	.04200	1.695	0	.34000	13.750
18	.04900	1.975		$\frac{11}{32}$ or .34370	13.875
17	.05800	2.350		$\frac{3}{8}$ or .37500	15.100
16	.06500	2.637	00	.38000	15.260
	$\frac{1}{16}$ or .06250	2.518		$\frac{13}{32}$ or .40620	16.320
15	.07200	2.920	000	.42500	17.125
14	.08300	3.350		$\frac{7}{16}$ or .43750	17.650
	$\frac{3}{32}$ or .09370	3.780	0000	.45400	18.300
13	.09500	3.850		$\frac{15}{32}$ or .46070	18.900
12	.10900	4.400		$\frac{1}{2}$ or .50000	20.000

TABLE V.

WEIGHTS AND VOLUMES OF VARIOUS METALS IN ORDINARY USE.

Metals.	Weight of a Cubic Foot. Pounds.	Weight of a Cubic Inch. Pounds.
Brass	488.75	.282
Brass, sheets	513.60	.297
Brass, wire	524.16	.303
Copper, cast	547.25	.317
Copper, plates	543.62	.316
Iron, cast	450.43	.260
Iron, plates	481.50	.278
Iron, wrought bars	486.75	.281
Lead, cast	709.50	.410
Lead, rolled	711.75	.411
Mercury, 60° F.	848.74	.491
Steel, plates	490.00	.282
Steel, soft	489.56	.283
Tin	455.68	.263
Zinc, cast	428.81	.248
Zinc, rolled	449.28	.260

TABLE VI.

WEIGHT, VOLUME, AND MEASURE OF WATER.

Weight.	Volume.	Measure.
8⅓ pounds	231 cubic inches	1 U. S. gallon
62½ pounds	1 cubic foot	7½ gallons
1 pound	27.7 cubic inches	.96 pint

SOLDERING, BRAZING, AND SWEATING.

SOLDERING.

35. Definition.—Welding is the process of uniting two pieces of metal by heating them to a high temperature, or until the surfaces become partly fluid, and then forcing them together by pressure or by hammering. The two pieces can also be united by covering the surfaces that are to be joined with a molten metal and immediately pressing them together; or the molten metal may be made to flow between them. This operation is called **soldering, sweating,** or **brazing,** according to the manner in which it is done and the metal used in making the joint.

36. Classes of Solder.—The fusible metal, or *solder*, used for this purpose may be divided into two kinds, which are known as *soft solder* and *hard solder*. **Soft solder** is composed of lead and tin, while **hard solder** consists of copper and zinc, or copper, zinc, and silver. The hard solder is often called **spelter,** and is used for brazing. The proportions in which the various metals enter into both the soft solder and the hard solder, and the uses of each, are fully explained later. The terms soft soldering and hard soldering, or brazing, come from the kinds of solder required for the classes of work to which they are applied.

37. Equipment. — The equipment required for ordinary soldering is very simple, consisting of a soldering iron, a fire-pot in which to heat it, the solder, and a flux to clean the surfaces that are to be united and to assist in the flow of the solder.

The **soldering iron,** sometimes called a **bolt** or **bit,** is a large piece of copper that is drawn to a point or edge and fastened to an iron rod having a wooden handle. This is shown in Fig. 22. The *solder* consists of equal parts of lead and

tin melted together and cast into a stick of convenient shape to handle. The **fluxes** vary according to the metal and the solder. The **fire-pot** may have any one of a variety

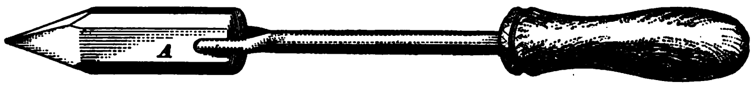

FIG. 22.

of forms. One of the best is a small, portable, charcoal stove; and one of the most convenient, a small gasoline furnace.

38. Soldering Fluid.—Of all the fluxes used for *soft soldering*, the **soldering fluid** possesses the greatest range of usefulness. It is made by placing some small clippings of zinc in muriatic (hydrochloric) acid that has been diluted with an equal quantity of water. The acid vigorously attacks the zinc, causing bubbles to rise. When the acid has dissolved all the zinc possible (which will take one hour or more), the liquid is strained and thinned by adding an equal bulk of water. A few scraps of zinc are then placed into the liquid to supply any deficiency that may exist or occur.

39. Tinning the Soldering Bolt.—Although a new soldering iron (copper) is always tinned, still it may be necessary to tin it in the course of time as the tin burns off. If the bolt has been used and the tin burned off in spots, it should be retinned. The copper head is filed bright and smooth with an old bastard file as far back as it is to be tinned. A lump of sal ammoniac and a stick of solder are then placed in readiness and the bolt put into the fire and heated slowly in order that the heat may soak in. When the heat in the forge acquires a green tinge (which is a sign that the copper is burning), the bolt is taken from the fire, and it will be found that it is just beginning to show its heat. The bolt is now rubbed clean with a rag, and one of the faces rubbed on the lump of sal ammoniac. This soon burns a trough into the lump and a few small

chips of solder are laid in this trough and the bolt rubbed over it again, thus melting the solder, which will stick to the copper. When all sides and the edge have been carefully tinned, the bolt should present a bright, glossy surface and be evenly tinned. The bolt may also be tinned by placing some sal ammoniac or resin on a block of wood and rubbing the bolt over it. When some of the material is melted, add some solder and rub until the bolt is well coated with the metal.

40. Making the Joint.—If two pieces of sheet brass, like those shown in Fig. 23, are to be soldered together, the surfaces to be soldered are first thoroughly cleaned with emery cloth and a little of the soldering fluid applied with a small brush or a feather. The bolt is then heated to a little less than a black heat. The heat can be determined by striking the bolt a quick glancing blow with the left hand; this brushes off the ashes and exposes the tin. If the bolt is hot enough, the tin is molten and has a streaked appearance when the hand is brushed over it. With a little experience, the proper heat can be easily recognized by this method.

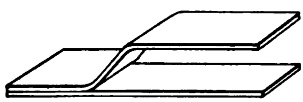

FIG. 23.

When the bolt has the proper heat, a drop of solder is melted from the stick and allowed to fall upon one of the fluxed surfaces and is melted to it with the hot bolt, care being taken to get the surface well tinned. The other piece is then prepared in the same way and both pieces placed in position and pressed together with the hot bolt. The heat from the bolt heats the piece of brass and melts the solder on the surfaces; the pieces are then held together until the solder has become hard. The acid that still adheres to the pieces must be washed off so as not to corrode the brass.

The method just given is the one generally used for making soldered joints. Of course, it is varied slightly to suit conditions, as, for instance, when two pieces are laid edge

to edge and the molten solder is drawn along by means of the hot soldering iron. In the main, however, this method is the one used for general work; and the ability to make neat and fast joints is a matter of practice.

41. Soldering Fluxes.—Different fluxes may be used on different metals. Sal ammoniac is the one that is commonly used on copper or brass; borax on iron; resin on tinned iron; and resin or tallow on lead. The soldering fluid, however, is the best all-around flux. By adding $\frac{1}{2}$ ounce of sal ammoniac to 4 ounces of the liquid, it can be used in soldering iron or steel without first having to tin the surfaces.

BRAZING.

42. Definition.—**Brazing** is a process of soldering with a less fusible solder (generally called *spelter*) which is made of copper and zinc, the proportions being varied to suit the requirements, copper making it hard: 1 part of copper and 1 part of zinc make a good soft spelter; 65 parts of copper and 35 parts of zinc make a good hard spelter; 13 parts of copper, 5 parts of zinc, and 82 parts of silver make a good spelter for soldering band saws. The component parts are fused together, then filed to a coarse powder, and made into a paste by the addition of calcined borax and water.

43. Brazing the Joint of a Pair of Tweezers.—As an illustration, a pair of tweezers, Fig. 24, affords a good example of flat brazing. The pieces are forged to the desired shape and tempered to a dark-blue color. The surfaces to be brazed are then cleaned, some of the spelter is applied to each surface, and the pieces tied together with a fine iron wire and heated sufficiently to melt the spelter. The heat may be applied with a blowpipe or by holding the pieces in a pair of hot tongs. When the spelter is melted,

the piece is cooled and the iron wire taken off. When the pieces are clamped in hot tongs, the iron wire is sometimes omitted, the pieces being placed in their proper

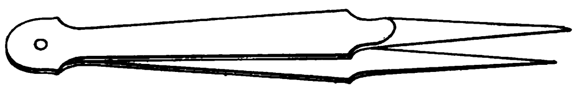

FIG. 24.

relation and the tongs depended on to keep them there, or stops may be arranged to determine the location of the pieces.

44. Brazing Tempered-Steel Articles.—In brazing a tempered-steel article, it is of great importance to heat the article so as to draw the temper as little as possible. The selection of the proper spelter or solder is also of great importance. If an article tempered to a dark-blue color is to be soldered without spoiling the temper, a solder that will melt below 600° F. must be used; as this solder is not so strong as the harder kinds, the soldered surfaces must be greater so as to give a hold equally as good.

When tempering steel articles that are to be brazed, the pieces are sometimes held together by snapping a small metal clip over the joint and so pressing it home that it will retain the pieces in their proper position. This clip is left on after the brazing is completed and while the piece is being tempered, provided the tempering is done after the brazing. By this means, the pieces may be brazed with hard solder, or silver, and subsequently tempered, the clip or clamp being removed after the work is finished.

45. Butt Brazing.—If two thin pieces are to be butt-brazed, the pieces must be held in position in a bench vise, hand vise, or clamp, and the heat applied with a pair of tongs or a blowpipe. The surfaces to be brazed are fluxed with borax and then clamped in position and a little spelter sprinkled on the side over the joint. Heat is then applied

by means of a blowpipe, a Bunsen burner, or a hot iron, until the pieces are hot enough to melt the spelter, which will then flow into the crack. By giving one of the pieces a slight tap on the end, the pieces are brought tightly together. They are then allowed to cool and the superfluous spelter is scraped off.

46. Lap Brazing.—Band saws are always lap-brazed, the two ends being filed to make an accurate joint. Silver solder is generally used, it being applied between the two surfaces; or the surfaces are coated with borax and the solder allowed to flow into the joint from the edges. Fig. 25 shows the two ends of a band saw filed for brazing. The

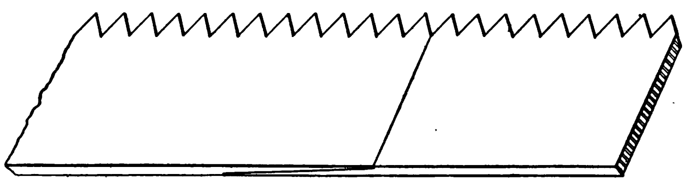

FIG. 25.

pieces are clamped together or tied with a wire after having been fluxed. The spelter is laid over the joint, or it may be put between the pieces. When the heat is applied, the spelter melts and the pieces must be squeezed tightly together. Silver coins contain 10 per cent. of copper, and make a good hard solder. The coin is pounded out until thin and then clamped between the surfaces to be brazed and the heat applied.

SWEATING.

47. Application.—**Sweating** is the name for another method of uniting two pieces by means of a solder. In boring out boxes for bearings, the pieces are sometimes sweated together and then bored and finished. After this they are again heated in order to melt the solder, and the

pieces taken apart. When brass boxes are sweated together, liners *a*, *a*, Fig. 26, are sometimes placed between them to allow for wear when they are in the machine. The illustration shows a pair of brasses *b*, *b* sweated together in this way. The faces of the brasses and the liners are planed smooth and rubbed bright. They are then heated in the forge, and, when hot, the brasses fluxed with sal ammoniac and tinned by the method employed in tinning the soldering copper. The liners, if of iron, are fluxed with borax and tinned. The pieces are then put together and heated sufficiently to melt the solder. If not heavy enough to make a tight joint, they are weighted down until cold. When the pieces have been bored out and finished in the machine shop, they are melted apart and the liners taken out.

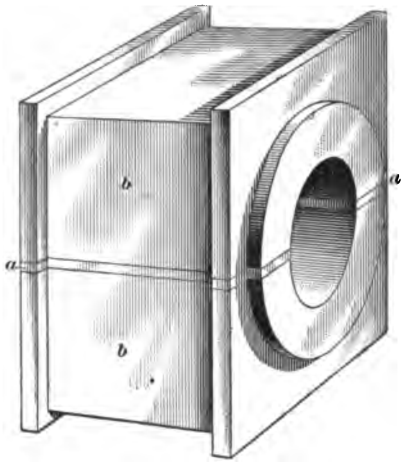

FIG. 26.

BENDING BRASS AND COPPER PIPE.

48. Annealing Brass and Copper Pipe.—Whenever a piece of brass or copper pipe or tubing is to be bent or shaped, the piece must first be annealed; this process should make it so soft that the smaller sizes can be bent by hand. Annealing is accomplished by evenly heating the metal to a dull-red heat and then plunging it into cold water; but care must be taken not to overheat brass.

49. Bending Small Tubing.—The simplest way to make a bend in a small tube is to turn a block of hard wood to the radius of the desired curve and then bend the pipe

about the block. When the radius is small, this may be done as shown in Fig. 27, *a* being the block about which the pipe is to be bent and *d* a square block of the same thickness, which is also clamped in a vise so as to act as a stop for holding the end of the pipe during the bending. After the two blocks *a* and *d* are so placed that the pipe can just be slipped between them, the end of the pipe *c* is slipped through to the point where it is desired to form the bend, and the other end carried about, as indicated by the dotted lines, to the desired angle. If a greater bend than 180° is made, it is sometimes difficult to remove the wooden block from the tubing. In some cases a groove is turned about the block *a*, the radius of the groove being equal to the radius of the pipe, so that the pipe will bed itself in the groove while being bent. This simple device will serve to bend pipe up to ¾ inch in diameter, and is sometimes used for larger sizes.

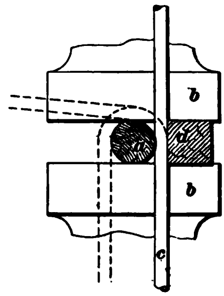

FIG. 27.

50. Support of Tubing While It Is Being Bent. In order to prevent the tubing from kinking or flattening while being bent, it is necessary to fill the inside with some substance. Sometimes, when there is a thread on each end of the tube, it is filled with sand and a cap screwed on each end, or the tube may be filled with water and the ends capped. When water is used as a filling material in a pipe, care must be taken to absolutely fill the pipe, for if it contains any air the latter may be compressed and allow the pipe to flatten at some point. The more common practice is to fill the tube with melted resin and allow this to harden. During bending the resin will be pulverized, but it will prevent the tube from flattening. After the bend is made, the resin can easily be melted and run out. Pipes less than ⅝ inch in diameter are bent without filling. Occasionally, if the metal is thick, it is possible to bend larger pipes in

this manner, but no chances whatever should be taken in a case of this kind.

51. Bending Large Tubing.—When it is necessary to bend large tubes, some special device must be used. The one shown in Fig. 28 has been found very convenient. This consists of two wheels *a* and *b* that are arranged as shown. The wheel *a* is clamped in a vise or by means of a special clamp. If it is required to bend greater angles than 90°, the vise or clamp must be so located that the lever *c* can

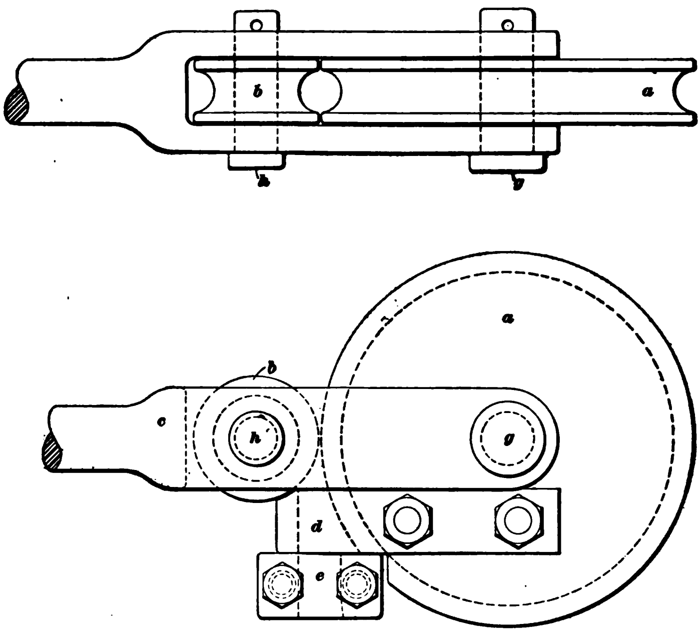

FIG. 28.

make the desired portion of a revolution. The lever *c* is pivoted to the pin *g* that passes through the center of the wheel *a*. The lever *c* is forked at the end and carries the wheel *b*. Attached permanently to the wheel *a* is a clamp or yoke *d* that is so arranged as to hold the tube tangent to the wheel *a*. The radius of the wheel *a* must be equal to that of the desired curve, and the outside of each wheel is

turned to such a form that when each wheel is in position they barely allow the tube to pass between them, thus preventing any tendency to flatten or buckle on the part of the metal that is being bent. The clamp *e* is placed on the tube to be bent at such a point that it will locate the point of tangency between the wheels *a* and *b* in the desired position. After the tube is in place, the lever *c* is carried around the wheel *a* and the pipe formed as desired. The lever *c* is then thrown back to its original position, shown in Fig. 28, the bolts of the clamp *e* are loosened, and the tube is taken out. The radius of the larger wheel *a* is made from $\frac{1}{32}$ to $\frac{1}{16}$ inch less than that of the corresponding radius of the pipe, to allow for the spring when the pipe is released. The wheel *b* is made as small as the stresses upon it will permit.

MISCELLANEOUS OPERATIONS.

FORGING STEEL.

52. The Recalescent Point in Steel.—When an ingot of steel is cast and allowed to cool, its temperature does not fall continuously, as might be expected. At about 2,600° F. it solidifies and from that point the temperature falls in equal divisions of time until the temperature of dull redness, between 1,300° F. and 1,200° F., is reached. Here the temperature suddenly stops falling for a period, and either increases slightly or remains stationary. After a short time it again falls regularly, as before, until the ingot is cold. The point at which the temperature remains constant or increases slightly is called the **recalescent point.** At it the internal structure of the steel undergoes important changes.

From the point of solidification the ingot begins to crystallize, but when the temperature reaches the recalescent point this crystallization ceases. If the ingot is heated again to any temperature less than that of the recalescent

point, the crystallization will not be affected; but as soon as this point is exceeded, the steel becomes amorphous in structure, the crystalline structure being destroyed by the heating.

53. Temperature for Forging Steel.—When a billet of steel is to be forged, its temperature should be above the recalescent point, and never below, as then the forging will tend to develop cracks and other faults in the interior of the piece. If it is worked at a greater temperature than that of the recalescent point, the steel is amorphous, or plastic, and not crystalline; consequently there will be no tendency to form fissures in the interior.

54. Effect of Using Too Light a Hammer.—The weight of hammer used in forging a piece of steel must be taken into account. In the early days of steel working, a great many forgings, such as crank-shafts of large size, broke while in ordinary service. This was at first attributed to gradual crystallization of the material under repeated shocks and strains. But later investigation proved that many of these failures were due to the use of too light a hammer in forging.

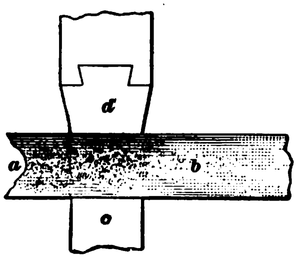

FIG. 29.

Fig. 29 illustrates graphically the effect of using too light a hammer for a given piece of work. The work is shown at *b*, the anvil at *c*, and the hammer head at *d*. The blows are not heavy enough to make themselves felt completely through the forging. As a consequence, only the outside fibers are readily forged, the interior remaining unchanged in structure, since the light blows are not sufficient to cause a *flow* of the metal at the center. It is not difficult to determine when too light a hammer is being used. The end of the billet will show that conclusively by presenting a concave appearance, as shown at *a*. The hammer blows on the outside fibers cause them to expand longitudinally, while the mass at the center remains

unchanged, thus giving the cup-shaped appearance illustrated. This stretching of the outside of the piece tends to pull the center apart and form spongy places, or even openings, along the center of the piece.

55. Effect of Using Proper Weight of Hammer. In order to secure a forging of homogeneous structure and equal strength throughout, the hammer must be so heavy that its blows will be felt to the center of the stock; that is, at each blow there must be a flow of the metal throughout the entire billet between the hammer and the anvil. When a hammer of correct weight is used, the end of the forging will appear as shown at *a*, Fig. 30. This convexity proves conclusively that the blows of the hammer have penetrated to the center of the mass, causing the metal to flow longitudinally under the compression, and thus bulging the end of the stock as shown, while the structure of the material will be uniform from center to outside. The parts have been given the same reference letters as in Fig. 29.

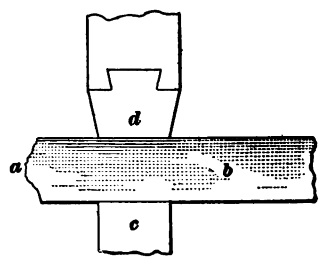

FIG. 30.

ESTIMATING STOCK.

56. The amount of stock necessary for any piece of work can be computed mathematically. Nearly all complicated forgings can be separated into several simple parts and the lengths of these measured and their weights calculated. But generally such estimates are made by direct measurements and the use of Tables II, III, IV, and V. The lengths are found by means of a templet, string, soft wire, dividers, or wheel. The line measured in curved work to find the amount of straight stock necessary is the *center* or *neutral* line, as this is neither shortened nor lengthened in the bending operations. The wire, or string, is laid on the neutral line of the drawing, templet, or work that is to

be duplicated and then straightened out on the stock. Likewise the dividers may be stepped along this line and the same number of steps repeated on the stock.

The measuring wheel, or circular rule, shown in Fig. 31, is a light metal wheel mounted in a handle, with an index, or pointer, past which the wheel moves. The circumference of the wheel is usually 24 inches and is marked in inches, halves, quarters, and eighths, though chalk marks are frequently used to indicate the positions of the wheel at the beginning and ending of a measurement. By carefully running the wheel along the center line of curved work and noting the number of turns, it can then be run on to the stock and a direct measure secured.

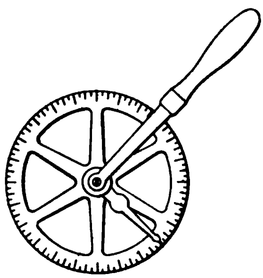

FIG. 31.

While theoretically the finished work contains the same weight of stock as the piece started with, there is a slight loss on account of scale and burning. Additional allowance must be made in cutting stock for the lap in welds. This extra length varies with the area of the piece and the style of weld and ranges from $\frac{1}{8}$ inch to 1 inch. Small stock usually requires a greater extra length than heavy stock.

TABLE VII.

SIZES OF RIVETS AND WEIGHTS PER 100.

Length Under Head. Inches.	3/8" Diam.	1/2" Diam.	5/8" Diam.	3/4" Diam.	7/8" Diam.	1" Diam.	1 1/8" Diam.	1 1/4" Diam.
1 1/4	5.4	12.6	21.5	28.7	43.1	65.3	91.5	123
1 1/2	6.2	13.9	23.7	31.8	47.3	70.7	98.4	133
1 3/4	6.9	15.3	25.8	34.9	51.4	76.2	105.0	142
2	7.7	16.6	27.9	37.9	55.6	81.6	112.0	150
2 1/4	8.5	18.0	30.0	41.0	59.8	87.1	119.0	159
2 1/2	9.2	19.4	32.2	44.1	63.0	92.5	126.0	167
2 3/4	10.0	20.7	34.3	47.1	68.1	98.0	133.0	176
3	10.8	22.1	36.4	50.2	72.3	103.0	140.0	184
3 1/4	11.5	23.5	38.6	53.3	76.5	109.0	147.0	193
3 1/2	12.3	24.8	40.7	56.4	80.7	114.0	154.0	201
3 3/4	13.1	26.2	42.8	59.4	84.8	120.0	161.0	210
4	13.8	27.5	45.0	62.5	89.0	125.0	167.0	218
4 1/4	14.6	28.9	47.1	65.6	93.2	131.0	174.0	227
4 1/2	15.4	30.3	49.2	68.6	97.4	136.0	181.0	236
4 3/4	16.2	31.6	51.4	71.7	102.0	142.0	188.0	244
5	16.9	33.0	53.5	74.8	106.0	147.0	195.0	253
5 1/4	17.7	34.4	55.6	77.8	110.0	153.0	202.0	261
5 1/2	18.4	35.7	57.7	80.9	114.0	158.0	209.0	270
5 3/4	19.2	37.1	59.9	84.0	118.0	163.0	216.0	278
6	20.0	38.5	62.0	87.0	122.0	169.0	223.0	287
6 1/2	21.5	41.2	66.3	93.2	131.0	180.0	236.0	304
7	23.0	43.9	70.5	99.3	139.0	191.0	250.0	321
7 1/2	24.6	46.6	74.8	106.0	147.0	202.0	264.0	338
8	26.1	49.4	79.0	112.0	156.0	213.0	278.0	355
8 1/2	27.6	52.1	83.3	118.0	164.0	223.0	292.0	372
9	29.2	54.8	87.6	124.0	173.0	234.0	306.0	389
9 1/2	30.7	57.6	91.8	130.0	181.0	245.0	319.0	406
10	32.2	60.3	96.1	136.0	189.0	256.0	333.0	423
10 1/2	33.8	63.0	101.0	142.0	198.0	267.0	347.0	440
11	35.3	65.7	105.0	148.0	206.0	278.0	361.0	457
11 1/2	36.8	68.5	109.0	155.0	214.0	289.0	375.0	474
12	38.4	71.2	113.0	161.0	223.0	300.0	388.0	491

INDEX

NOTE.—All items in this index refer first to the section (see the Preface) and then to the page of the section. Thus, "Annealing 58 6" means that annealing will be found on page 6, of section 58.

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